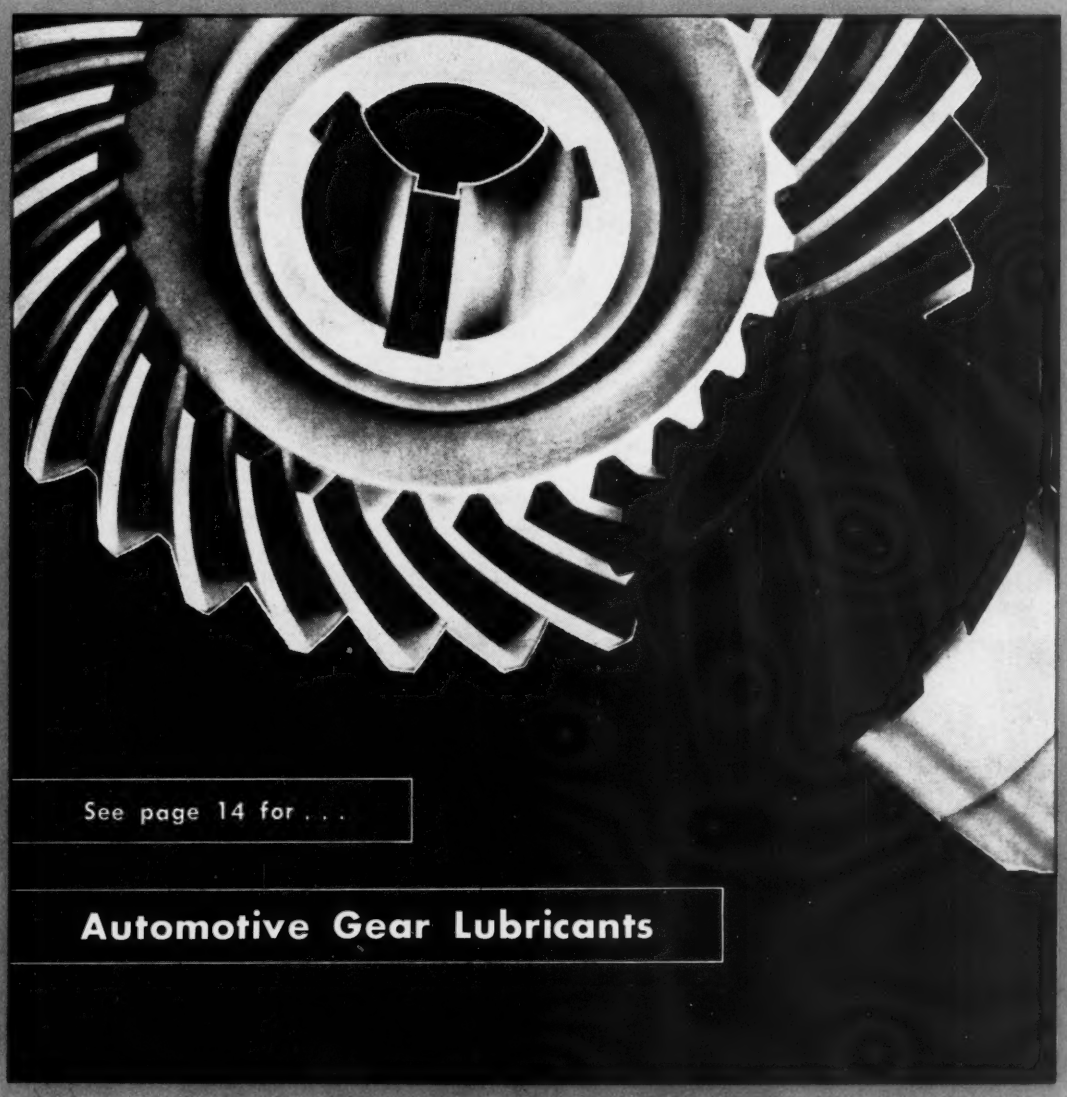
Vol. 17, No. 1 January, 1961

# LUBRICATION ENGINEERING

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



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Automotive Gear Lubricants

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

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***As we begin this New Year—1961 —the Society expresses thanks to its Industrial Members for their support.***

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**U. S. STEEL CORPORATION**
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525 William Penn Place
Pittsburgh 30, Pa.
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**WESTINGHOUSE ELECTRIC CORP.**
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Beulah Road Churchill Borough
Pittsburgh 35, Pa.
**(John Boyd)**

**New Members in 1961*

Volume 17, No. 1
January, 1961

# Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

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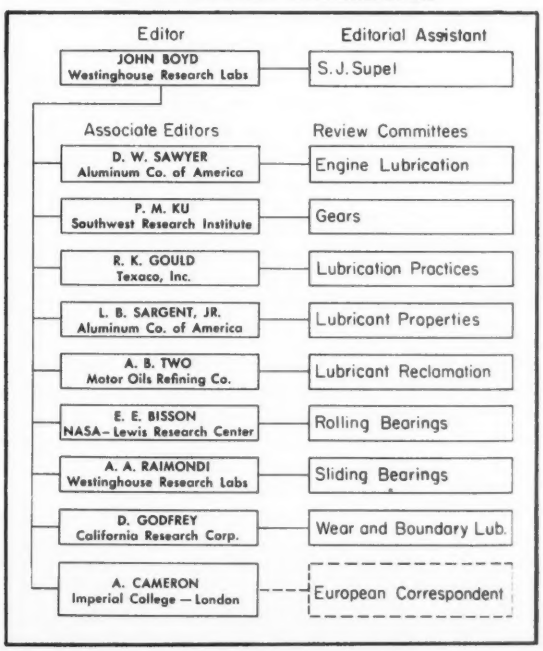
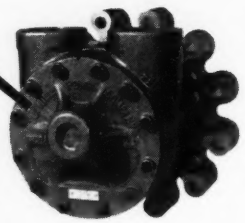
**EDITORIAL REVIEW ORGANIZATION**



# POSITIVE LUBRICATION of Halliburton "fracturing" units with TUTHILL PUMPS



The HT-400 truck mounted pumping unit is a proud manifestation of Halliburton's 35 years of leadership in oil field service operations. These units were especially developed for "fracturing" . . . the breaking apart and propping open of oil formations by hydraulic or fluid pressure . . . in which oil mixed with selected grades of sand is pumped into oil wells at extremely high pressures. A pair of HT-400 units, mounted side by side, can deliver over 1,000 hydraulic horsepower . . . move over 42 barrels of oil per minute . . . or, with modifications, reach pressures of 20,000 psi.

For positive lubrication and cooling Halliburton selected Tuthill model 6C pumps as an important component of the rugged HT-400. Special modifications of the shaft and mounting bracket by Tuthill's application engineers permit the 6C to be assembled into the Halliburton unit with the greatest possible ease.

## Over 800 standard models

This model 6C is one of over 800 models in Tuthill's complete selection. These include reversing pumps, special pump motor-combinations, and stripped units for OEM use. They may be furnished with a wide variety of modifications including built-in relief valves, automatic reversing feature, special porting arrangements, special seals or shaft extensions, and many more.

Probably a Tuthill standard model can provide an economical, dependable answer to your pumping problem. But if your application requires it, Tuthill's engineers will develop modifications or special features to provide the best possible solution to your pumping problem.

Catalog 100 describes the complete Tuthill line. Write for your copy. Or forward information on your application, so we can indicate how our engineers may be able to provide savings.

*Tuthill manufactures a complete line of positive displacement rotary pumps with capacities from ⅛ to 200 gpm; for pressures to 1500 psi; speeds to 3600 rpm.*

PUMPS FOR YOUR PURPOSE

**TUTHILL PUMP COMPANY**

971 East 95th Street, Chicago 19, Illinois

# LUBRICATION IN THE NEWS

*The Society will not be responsible for the accuracy of statements made in this column. Any reference to proprietary products does not imply an endorsement of such products by the Society.*

## ARMY ISSUES QUALIFIED PRODUCTS LIST OF HYDRAULIC FLUIDS

The Ordnance Corps., Department of the Army, has announced its intention to establish a *Qualified Products List for Hydraulic Fluid, Petroleum Base, For Machine Tools*, under Specification MIL-H-46001 (ORD). Companies which have a product meeting the requirements of this specification may contact the Commanding Officer, Rock Island Arsenal, Rock Island, Illinois, Attention: Laboratory, for an opoprtunity to have their products tested. In making future awards, awards will be made only for such products as have been tested and approved for inclusion in the Qualified Products List. (Source: The Ordnance Corps, Department of the Army, Rock Island Arsenal, Rock Island, Ill.)

## C. S. M. A. PLAYS ROLE IN ADOPTION OF SAFETY LEGISLATION

In summarizing the accomplishments of the Chemical Specialties Manufacturers Association during 1960, Dr. George W. Fiero, assistant manager for lubricating and process oils with Humble Oil and Refining Company's Esso Standard Div., New York City, and C. S. M. A. president, pointed out that the association's public service and industry activities have aided in the adoption of regulations, legislations and administrative procedures which make an important contribution to consumer safety.

As an example, Dr. Fiero cited the growing acceptance of the need for hydraulic brake fluid laws by a sizeable number of states. It was pointed out that the Automotive Division of the C. S. M. A. has played a major role in obtaining passage of the laws, and nineteen state legislatures have now enacted such safeguards. Further, the Automotive Division of the C. S. M. A. also developed the first standard hydraulic fluid. Dr. Fiero stated, "By prohibiting the use of dangerous, substandard fluids, accidents have been avoided and lives saved." (Source: Chemical Specialties Manufacturers Association)

## USAF REPORT DESCRIBES STORAGE CHARACTERISTICS OF GREASE

Available from OTS is an Air Force report on the storage characteristics of 11 aviation greases at room temperature over a two-year period. The report is: *Storage Stability of Fluids and Lubricants: Part 2—Room Temperature Storage of Aircraft Greases.* J. B. Christian, Wright Air Development Division, U.S. Air Force. Apr. 1960. 20 pages. (Order PB 161808 from OTS, U.S. Department of Commerce, Washington 25, D.C., 50 cents.)

Eleven aviation greases in five Air Force specification categories were placed in storage at room temperature for 24 months as part of an Air Force research project to test the storage stability of various fluids and lubricants. The greases were examined and property changes recorded at the end of 12, 18, and 24 months storage. Three out of four greases in one category no longer met minimum specifications; all other greases did. The storage stability characteristics of all 11 greases are listed in table form. (Source: OTS, United States Department of Commerce).

## INSTITUTE OF PLANT ENGINEERS SPONSOR SYMPOSIUM

The Council of the Institute of Plant Engineers has announced plans to sponsor a Symposium on Lubrication Engineering. The Symposium, the first of its kind to be held in England, will take place on March 23, 1961 in the Meeting Hall of the Institution of Mechanical Engineers, London, England. The symposium will consist of four papers by recognized authorities in the field of lubrication engineering.

The program will be as follows:
9:45 a.m. Opening remarks by the President of The Institution of Plant Engineers, Mr. E. C. Stevens, M.A. (Cantab.), B.Sc.Tech., A.T.I.
**Session 1**—Chairman, Dr. H. C. O'Connor, Ph.D., B.Sc., A.M.I. Mech.E.
10:00 a.m. "Lubrication Engineering and the Petroleum Industry," by Mr. R. A. Marshall, B.Sc., A.M.I. Mech. E. and Mr. H. B. Chadwick, M.A. (Shell Refining Company Ltd., Stanlow).
11:00 a.m. Morning Coffee.
11:30 a.m. "Lubrication Engineering and the Chemical Industry," by Mr. W. T. Pittman, B.Sc. (Billingham Division of Imperial Chemical Industries Ltd.).
12:30 p.m. Buffet Luncheon.
**Session 2**—Chairman, Mr. G. D. Jordan, M.Eng., A.M.I. Mech.E., A.M.I. Prod. E., President-Elect of The Institution of Plant Engineers.
2:00 p.m. "Lubrication Engineering and the Steel Industry," by Mr. H. Harber, B.Sc. (Eng.), (The Steel Company of Wales Ltd.).
3:00 p.m. Afternoon Tea.
3:15 p.m. "Lubrication Engineering and the Plant Manufacturer," by Mr. J. A. McCurdy, M.Eng., A.M.I. Mech.E. (Turbine-Generator Division, Associated Electrical Industries Ltd.).
4:15 p.m. General Discussion and Summing Up by the President. (Source: The Institution of Plant Engineers, London, England)

## AMERICAN METAL CLIMAX SAYS 1960 NET WILL RISE AT LEAST 38% FROM '59

American Metal Climax, Inc. looks for earnings this year amounting to $2.70 a common share, a 38% gain over 1959.

Frank Coolbough, president, states that the company's domestic operations are expected to contribute $2.10 a share to the 1960 earnings. The largest contributor to the 1960 domestic results, he said, will be $1.55 a share from molybdenum operations.

Dividends received from the company's investments in Africa account for 60 cents a share. Concerning African conditions, Mr. Coolbough said, "There is going to be a political transition in Northern Rhodesia and we are not pretending to guarantee the outcome. But we believe there is a good chance that industrial disturbances can be avoided." (Source: Wall Street Journal, Nov. 23, 1960).

# NEW PRODUCTS

## NEW HIGH TEMPERATURE METAL FORMING LUBRICANT ANNOUNCED

Phosphatherm RN, a metal forming lubricant for use at temperatures between 1100 and 2200 F, is announced by The Alpha-Molykote Corporation. The lubricant is said to prevent galling, scoring, and metal pickup when forming most types of common steels, steel and copper alloys and the exotic metals at elevated temperature.

Supplied as a dry white powder, when Phosphatherm RN is mixed with ordinary tap water it forms a viscous liquid which adheres to metal surfaces. If the powder is applied directly to a hot surface above 400 F it will appear to boil, then fuse to the surface. The coating forms a lubricating film resisting extreme temperatures and which will not oxidize when the work piece is heated to between 1100 and 2200 F.

To obtain more information write: The Alpha-Molykote Corp., 65 Harvard Ave., Stamford, Conn.

## IMPOLENE PLASTIC TUBING FOR HIGH PRESSURE AND HIGH TEMPERATURE

Impolene, a new stabilized polypropylene tubing for use at operating temperatures up to 300° F. and working pressures to 450 psi, has been introduced by Imperial-Eastman Corporation, Chicago, Ill.

It is stated that Impolene is corrosion resistant; can be repeatedly steam sterilized; and has 30 to 50 times the life of Nylon at elevated temperatures. With a nearly zero water absorption, Impolene has low absorption of mineral and vegetable oils.

More information is available from Imperial Eastman Corp., 6300 West Howard St., Chicago 48, Ill.

## GEAR ANALYZER PRODUCED

Rotiform Co., Santa Monica, Calif., announced the production of a gear analyzer which permits direct observation of shaft backlash angle due to an alternately applied clockwise and counterclockwise torque, and permits detection of minute shaft motion while determining breakaway torque. Both the backlash and breakaway torques are readily adjustable over a wide range of values. Various mounting adapters accommodate gear heads, servo systems, potentiometers, switches, valves, etc.

The equipment reportedly employs dual purpose lever locks for restraint against shaft rotation and for positive zero position return to achieve measurement of shaft rotation within one minute of arc accuracy. A double collet sliding coupling transmits the backlash and breakaway torques which may be pre-set to any desired values within the selected instrument ranges, extending from .002 to 48 oz. in.

Available from Rotiform Co., 1509 Colorado Ave., Santa Monica, Calif.

## MINIATURE FILTER-REGULATOR-LUBRICATOR INTRODUCED

A new, compact air line filter-regulator-lubricator assembly has been introduced by Watts Regulator Company. Designed for applications where space is limited or low flow requirements are a factor, the miniature unit is available in ⅛" and ¼" sizes, with maximum pressure 150 psi. The filter features a 2-micron porous bronze element and the lubricator incorporates the Watts' by-pass principle which is said to provide lubrication at flow rates from .2 to 15 cfm without excessive pressure drop. Both fill plug and oil feed adjustments are interchangeable front to rear.

For more information write: Watts Regulator Co., Lawrence, Mass.

## NEW SPRAY-ON DRY LUBRICANT

Hercules Packing Corporation, Alden, New York, announces the development of Moly-Duolube, a new dry lubricant.

Packaged in an aerosol dispenser, Moly-Duolube lubricant utilizes Molybdenum Disulfide as its principal ingredient, and is said to be non-toxic, inert and is recommended wherever grease would be objectionable.

Produced in two styles, "Air Drying" and "Bake on", the lubricant is suitable for lubricating electronic equipment such as pivot points of relay, switches, sockets, dials and solenoids. The resistance to corrosion of the "Bake-on" type renders it suitable for indoor and outdoor uses.

Additional information is available from Hercules Packing Corp., 11061 Walden Ave., Alden, N.Y.

## NEW HELICAL GEAR DRIVE PUMPS AVAILABLE

Two new series of internal gear rotary pump assemblies by The Wayne Pump Company feature integral helical gear reduction assemblies mounted directly to the pump.

The new series, described as "CJ" and "DJ," are designed to handle a variety of thick and thin liquids.

With the advantages of lighter weight and small size, the pump capacities range from 26 GPM for the smallest model in either the "CJ" or "DJ" group to 252 GPM for the largest. The pumps are rated up to 100 PSI, and motor sizes range from 1½ to 10 HP.

The oil-immersed gear drives are AGMA rated, and can be provided for pump speeds of 635, 515 or 420 RPM from standard 1750 RPM motors. Different motors can be substituted with "plug-in" simplicity while under field conditions.

For complete details, write: The Wayne Pump Co., Griffin St., Fort Wayne, Ind.

## NEW FILTER ELEMENT DEVELOPED

Commercial Filters Corporation has developed the CFC Porous Metal Filter Element for the filtration of fluids with characteristics incompatible with ordinary filter media, particularly corrosive, high temperature, and high viscosity fluids. The element is cleanable by firing, chemical or ultrasonic treatment or back flushing.

Available from Commercial Filters Corp., 2 Main St., Melrose 76, Mass.

## UNIVERSAL MULTI-RATIO GEAR BOX

PIC Design Corp., a subsidiary of Benrus Watch Company, Inc., announced that a newly developed Universal Multi-Ratio Gear Box is now available.

The Multi-Ratio Gear Box is designed as a developmental speed reducer and increaser, with 10 basic ratios (5 reductions and 5 increases), with standardized mounting dimensions to insure quick and accurate assembly with all hangers, breadboard plates and development components. No tools or critical adjustments are necessary when changing ratios, as the box is simply placed in the correct position for the ratio desired.

To obtain more information, write: PIC Design Corp., 477 Atlantic Ave., East Rockaway, N.Y.

# Can you gamble on slim safety margins in low cost jet lubes?

Safety margins in synthetic jet lubes are being minimized by efforts to achieve lowest possible cost. This is not so when formulations are based on the Emolein® Azelates. These proven diesters provide the comfortable safety margins desired by engine manufacturers and commercial airlines.

Because diesters are such a major component in compounded lubricants, the use of azelates reflects directly in improved performance in terms of rubber swell, flash point, volatility, additive response, load carrying capacity and temperature-viscosity behavior.

Be sure that your jet lubes have the margin of safety provided by the Emolein Azelates. It is the *safe* way to save.

Emery INDUSTRIES, INC.

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**Emery Industries, Inc.**
Dept. Y-1, Carew Tower, Cincinnati 2, Ohio

☐ Please send Bulletin #409B covering Emolein Azelates.
☐ Please have an Emery Technical Representative call.

Name _____ Title _____

Company _____

Address _____

City _____ State _____

# PRODUCT LITERATURE

### BULLETIN ON PRESSURE REGULATORS RELEASED

Details on Reliance Type CBVA 400 and 600 pressure regulators for reducing and boiler fuel applications are given in Bulletin 132 released by American Meter Company, Erie, Pa. Both regulators are for use on transmission, distribution, and industrial systems where reliability and minimum maintenance, and advantages of underspring loading are required. Model 600 has a valve travel limit screw for boiler fuel regulation.

The Bulletin provides recommended spring ranges, diaphragm chamber sizes, valve dimensions, exterior dimensions, shipping weights, and design and performance features with detailed cutaway illustrations of Models 400 and 600.

Bulletin 132 may be obtained from American Meter Co., 920 Payne Ave., Erie 6, Pa.

### NEW CATALOG ON CONTROL VALVES

A new 8-page catalog J170-1 contains engineering information on OPW-Jordan Corporation Sliding Gate and Plate Control Valves, recommended for use on steam, water, air, oil, gas and chemicals. J170-1 gives applications, operating features and characteristics, materials of construction, pressure and temperature limitations, photos and cut-sections, flow curve, sizing charts and sample specifications.

Write OPW-Jordan, 6013 Wiehe Road, Cincinnati 13, Ohio.

### BROCHURE LIST INDUSTRIAL CHLORINATED PARAFFINS

Dover Chemical Corp. announces the availability of a new brochure, "Paroils for the Lubricant Industry," which gives a listing of all available Chlorinated Paraffins from highly fluid liquid grades to the resin grades, and with chlorine contents varying from 40 to 80%. Dover Chemical Corp. produces chlorinated paraffins for industrial use.

Available by writing to Dover Chemical Corp., West 15th Street, Dover, Ohio.

### HYDRAULIC TUBING-FITTING CATALOG SECTIONS OFFERED

Three new catalog sections dealing with a wide range of hydraulic products, their application, and pertinent design data are announced by Formrite Tube Company, Two Rivers, Wisconsin. Included in the catalog material is a 31-page "Tubing and Fitting Section," 12-page "Hose Section," and 16-page "37° Flare Fitting Section." The catalog sections are compiled to provide assistance to product development engineers.

For further information write: Formrite Tube Co., Two Rivers, Wis.

### LUBRICATED PLUG VALVE LITERATURE KIT AVAILABLE

Walworth Company's newly created Lubricated Plug Valve Division is offering a kit consisting of four bulletins covering various aspects of the lube-valve.

Individual bulletins, all dealing with lubricated plug valves, are titled: *Service Fleet* (4pp), *Rolotork* (8pp), *High Strength Cast Iron* (4pp), and *Lubricating Manual* (12pp). All are printed in 2-colors with numerous diagrams and illustrations.

Of particular interest to LPV users is a 4-page section of the Lubricating Manual which deals with the selection of the proper lubricant to suit the service of the valve. Over 600 applications are listed.

Complete kits or individual bulletins available from Walworth Co., Lubricated Plug Valve Div., 750 Third Ave., New York 17, N.Y.

### BULLETIN ON PETROLEUM ADDITIVES PUBLISHED

R. T. Vanderbilt Co., Inc., New York City, has made available the newly published bulletin, "Petroleum Additives." The booklet gives a tabular summary of the properties and uses of Vanderbilt's line of commercial chemical products used by the Petroleum industry. Vanderbilt petroleum additives include antioxidants, corrosion inhibitors, metal deactivators, bactericides, polymer stabilizers and rust inhibitors—materials used in a variety of fuels and lubricants.

Experimental samples and additional information are available from R. T. Vanderbilt Co., Inc., 230 Park Ave., New York 17., N.Y.

### RELIEF VALVES FEATURED IN NEW CATALOG

A new 4-page catalog of handwheel valves for oil by-pass relief applications has been announced by Fulflo Specialties. These valves are based on Fulflo standard valves used in hydraulic systems, oil-feeding systems, and other fluids-under-pressure uses. The catalog shows variations of Fulflo valves such as stainless trim, panel mounting design, wrench-type or wing-type locking nuts and others. Each valve is said to be capable of controlling pressure over a specified range, with easy adjustment provided by the handwheel. The pressure range of any valve can also be changed by substituting a different pressure spring.

Catalog may be obtained by writing to the Fulflo Specialties Co., Inc., 415 Fancy St., Blanchester, Ohio.

### INSTRUMENT AND FILTER CATALOG PUBLISHED

The 44-page publication by Gelman Instrument Co., "Dust Topics," describes new equipment for dust surveys, air pollution analysis radiation protection and special submicron filtration apparatus.

Apparatus and techniques of measuring and filtering sub-micron contamination is discussed in "Dust Topics." Devices are illustrated which allow determination of airborne dirt in ultraclean areas. Special filters are described which can remove particles of less than 0.5 micron from missile hydraulic and fuel lines.

To obtain copy, write: Gelman Instrument Co., 106 N. Main St., Chelsea, Mich.

### ANTI-SCORING LUBRICANT BROCHURE

A four-page brochure describing CMD extreme pressure anti-scoring lubricant for extreme pressure in machine tool and other manufacturing processes has been published by the Chicago Manufacturing and Distributing Co. The brochure indicates that CMD Extreme Pressure Lubricant will withstand 20 tons pressure per square inch without break-down allowing metal-to-metal contact and consequent scoring, galling, etc. Uses of the product are described for lubrication in such operations or equipment as lathe centers, steady rests, thrust bearings, broaching, extruding, swaging, die-set posts, cams, machine ways, tapping, etc.

Brochure available from Chicago Manufacturing and Distributing Co., 1904-P West 46th St., Chicago 9, Ill.

## SECTION NEWS

**Buffalo** – Mr. H. Hessing, National Aeronautics and Space Administration, will speak at the January 18 meeting. His subject will be "Lubrication in Space."

**Cleveland**—Panel Meetings have been arranged for the February 28 and March 28 meetings. Machine tool builders, bearing manufacturers, and oil company representatives will discuss the role of non-corrosive dual purpose lubricating and cutting oils at the February 28 meeting. Panel Members: Mr. William Eismann, Manager of Lubricant Sales, E. F. Houghton Co., Philadelphia, Pa.; Mr. Harold Vollnik, Lubrication Specialist, National Refining Co., Flint, Mich.; Mr. Howard Peeples, Lubrication Engineer, Timken Roller Bearing Co., Canton, Ohio; Mr. Charles R. Gillette, Mfg. of Research Chemistry, New Departure, Bristol, Conn.; Mr. James H. Smith, Consulting and Administrative Engr., The Nat'l Acme Mfg. Co., Cleveland, Ohio; Mr. Paul B. Kuzmak, Mgr. of Engineering, The New Britain Machine Tool Co., New Britain, Conn.

**Hudson-Mohawk**—Mr. Robert L. Johnson, NASA, is scheduled to speak on "Bearings for Space Applications" at the February 23 regular meeting.

**Saginaw Valley**—Designated as Ladies' Night, with "1001 Arabian Nights (or less)" as the theme, the January 26 meeting will feature Mr. John W. Mestrezat, J. N. Fauver Co.

**Montreal**—"Oils, Additives, and Lubrication" will be discussed at the February 1 meeting by Mr. Stanley M. Pier, Cities Service Company Limited.

**Chicago** – February 16 is called "A Night of Bliss" and Ladies' Night, featuring The Mid States Four.

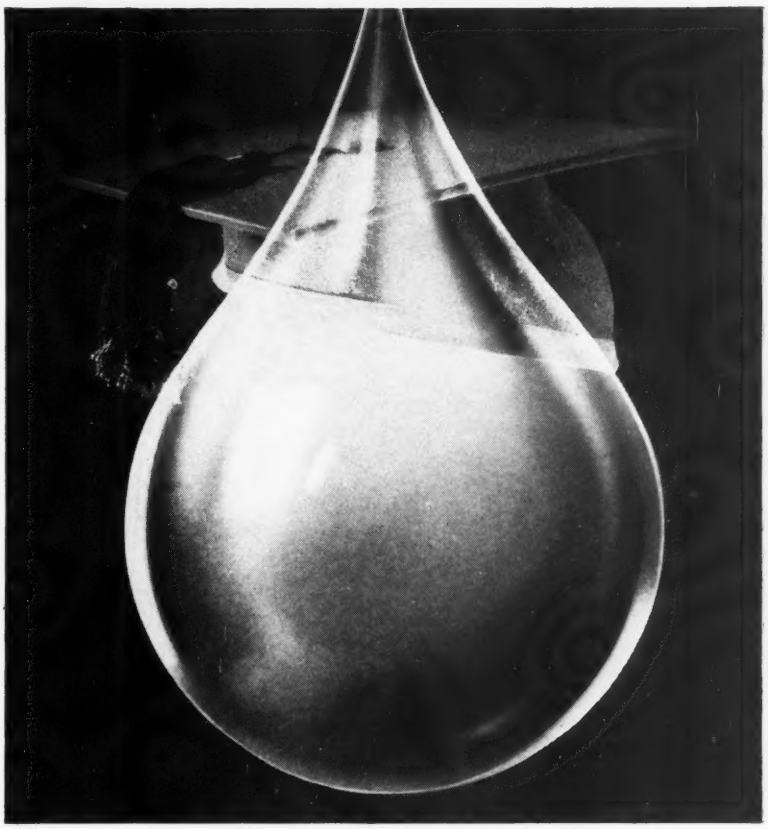
**Baltimore**—ASLE President, L. O. Witzenburg, is scheduled to speak at the January 17 meeting on the subject, "Worm Gear Design and Lubrication."

**Boston**—An Educational Course will be sponsored by the Boston Section, March 20, 1961, at a one-day symposium. The course, entitled "The 5 R's of Lubrication," will be based on a series of articles which appeared in the May, 1959 issue of *Lubrication Engineering*.

The course will be presented at the 1200 Beacon Street Hotel, Boston, at a cost of $15.00 per person—the same for both ASLE members and non-members. For the evening program, an attempt is being made to obtain Mr. Daniel May, of the Boston Edison Co., to give a presentation and film on the newly installed Electric Atomic Power Plant at Rowe, Mass.

(*Continued on page* 52)


# HOW TO educate



# a drop of oil!

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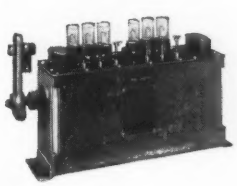

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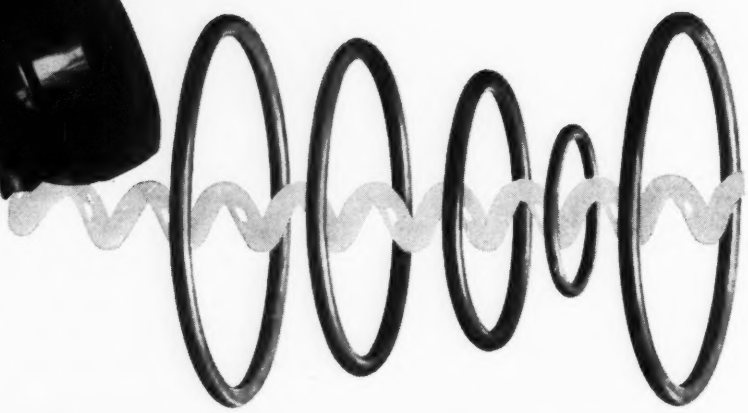

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6342

# SOCIETY NEWS

The following is a summary of committee reports and Board actions at the October 18, 1960 Board of Directors Meeting, Boston, Massachusetts.

**EXECUTIVE COMMITTEE**—Announced an approximate 11% advertising rate increase in *Lubrication Engineering*, effective January, 1961, to offset the increased production and editorial costs. Discussed with Regional Vice-Presidents, their role in promoting ASLE at the Section level. The Executive Committee reminded the Regional Vice Presidents of their new responsibilities in line with the constitution and that they should expand activities so as to make Sections aware that national officers are close and sympathetic to their needs and problems.

**TREASURER'S REPORT**—The Treasurer reported that our financial situation seemed to reflect the general economic trend throughout the country and that disbursements will exceed receipts by $10,000 for the year. Disbursements will be approximately $1,500 less than anticipated, but receipts from membership dues and advertising income will be approximately $11,000 less than anticipated. It was pointed out that a more representative number of industrial members out of the 1,000 companies now having individual members in ASLE would have easily offset this year's deficit (See Presidential Council below). As it is now, the Board authorized the use of reserve funds until year-end.

**PRESIDENTIAL COUNCIL**—The Council reported that the industrial membership drive had received poor response to date. It was suggested that solicitors be re-contacted and asked to volunteer the companies they would prefer to contact, in the interest of improving the follow-up.

**ADVERTISING *(Lubrication Engineering)***—An upturn in space sales in the latter half of the year offset the loss in the first six months. Total advertising revenue will be slightly greater than 1959. A re-arrangement of publisher's representatives for 1961 is planned, which will result in a saving to the Society. The advertising outlook for 1961 is generally encouraging.

**LUBRICATION ENGINEERING** — Enthusiastic approval of the new editorial program was reported (a detailed account of the readership study will appear in the February issue), and the Board authorized continuation of the program in 1961. The readers service card received excellent acceptance and the Board authorized its continuation in 1961.

**RULES COMMITTEE**—This committee has set a target date of 1962 for re-writing tentative by-laws and operating rules into a finished work; revising model section by-laws to conform to the new constitution; reviewing all section by-laws after they have been revised to conform with new model by-laws; reviewing operating manuals of Joint Technical Committee and Joint Industry Lubrication Council.

**JOINT LUBRICATION CONFERENCE COMMITTEE**—ASLE once more enjoyed an advantage in the number of sponsored papers, with ASLE sponsoring seventeen and ASME thirteen. The newly organized ASME Spring Symposium has been expanded into a Conference. This suggests a need for the two societies to cooperate to reduce the number of competing meetings.

**EDUCATION COMMITTEE**—The committee is being reorganized to serve a more useful function. An education course is scheduled at the time of the Annual Meeting and will have appeal to the research group as well as the practical level. The Board restated the philosophy that local sections should receive aid and assistance from the national committee in organizing an education course.

**NEW SECTIONS COMMITTEE**—As previously reported, the Board authorized the issuance of a Charter to the Oklahoma Section with headquarters in Tulsa, Oklahoma.

**PROGRAM COMMITTEE (1961)**—The 1961 Annual Meeting Program will include the previously scheduled Bearing Symposium. The program appears to be in good shape—with respect to both quality and quantity, especially now that the revised review procedure has been put into effect. (See LE, Nov. 1960.)

**TRANSACTIONS**—Every effort is being exerted to complete publication of Volume 3 by the year's end. Action has been taken to assure that 1961 will see this publication on schedule.

**MEMBERSHIP ROSTER**—The Board authorized the publication of an ASLE Membership Roster in the September 1961 issue of *Lubrication Engineering*.

**ANNUAL MEETING SITES COMMITTEE**—The Board voted to hold the 1965 Annual Meeting at the Penn-Sheraton Hotel, Pittsburgh, Pa. Other society Annual Meetings are as follows: April 11-13, 1961, Philadelphia, Pa.; May 8-10, 1962, St. Louis, Mo.; May 7-9, 1963, Chicago, Ill., May 5-7, 1964, New York City.

**ANNUAL MEETING (1961) COMMITTEE**—Reports good progress and all plans and arrangements are being made for the largest Annual Meeting in the history of the Society.

**EXHIBITS COMMITTEE**—Reports that about half of the exhibit space has been sold so far, and it is actively pushing the project at this time.

**HANDBOOK ADVISORY COMMITTEE**—Considerable work remains to be done on the Handbook on Lubrication, which is being published by McGraw Hill, under the sponsorship of ASLE. Publication target date is still 1961.

---

ASLE is proud to announce the first foreign industrial member of the Society—PAZ OIL CO., LTD.—of Haifa, Israel. Mr. Y. Gavish, Technical Advisor, has been appointed as the representative. Mr. Gavish stated during a recent visit to this country, "The management is convinced that close cooperation with your important Society will be most beneficial to the activities in this country."

## ASLE NEW MEMBERS—NOVEMBER, 1960

PITTSBURGH

**WILLIAM J. CUSHING**
Timken Roller Bearing Co.
Pittsburgh, Pa.

**JOHN K. SARGENT**
Kerns United Corp.
Pittsburgh, Pa.

NEW YORK

**EDWARD A. BANIAK**
Texaco Research
Beacon, New York

**MILTON ROSENBERG**
Geigy Chemical Corp.
Yonkers, New York

**W. J. POWERS**
Enjay Chemical Co.
New York, New York

PHILADELPHIA

**RUSSELL H. CRAWFORD**
Gulf Oil Corp.
Glenside, Pennsylvania

**THOMAS G. MAQUIRE**
E. F. Houghton & Company
Philadelphia, Pennsylvania

INDIANAPOLIS

**JAMES LANDES**
Elanco Products Co.
Div. of Eli Lilly Co.
Indianapolis, Indiana

**JAMES H. SHULTZ**
Poly Chem Inc.
Indianapolis, Indiana

(*Continued on page* 10)

## SOCIETY NEWS

(*Continued from page 9*)

BOSTON

**FRANCIS E. MURPHY**
Walworth Company
Braintree, Mass.

TWIN CITIES

**ALBIN E. LARSON**
Midland Cooperatives, Inc.
Minneapolis, Minn.

DETROIT

**DEWEY R. BUTT**
Canfield Oil Co.
Detroit, Michigan

**CHARLES W. IRWIN**
Shell Oil Co.
Detroit, Michigan

NORTHERN CALIFORNIA

**MELVIN A. AYERS**
Std. Oil Company
Richmond Refinery
Richmond, California

**HARRY P. HARMON**
S T P Sales Co.-Div.
Mathy Company
Emeryville, California

SYRACUSE

**RICHARD F. STIMER (R)***
New Process Gear Div.
Chrys Corp.
Syracuse, New York

ST. LOUIS

**BERNARD J. SEXAVER**
American Brake Shoe Co.
St. Louis, Missouri

MONTREAL

**JAMES K. STEWART**
Shell Oil Co. of Canada Ltd.
Montreal, Que., Canada

**JAMES STODDART**
Canada Cement Co. Ltd.
Montreal, Que., Canada

HUNTINGTON-CHARLESTON

**DONALD R. CLERE**
Sun Oil Co.
Kenova, W. Virginia

UNAFFILIATED

**IRA L. CUPPLES**
Arkansas Fuel Oil Corp.
Little Rock, Arkansas

**DUDLEY C. JACKSON (R)**
Dudley C. Jackson, Inc.
Birmingham, Alabama

**CLAUDE E. SPAINHOUR**
Crossett Paper Mills
Crossett, Arkansas

**ROBERT S. PIKE**
Texas Refinery Corp.
Auburn, Maine

FOREIGN

**FRIEDRICH J. KROEG**
Caltex Oil (Germany) GmbH
Hannover, Germany

CHICAGO

**CLARENCE E. ALBERTSON**
Borg Warner Corp.
Des Plaines, Illinois

**JAMES H. BARDEN**
Stewart-Warner Corp.
Chicago, Illinois

**F. S. HAMMERSTEIN**
Mobil Oil Co.
Chicago, Illinois

**STANLEY HOEFER**
D. A. Stuart Oil Co. Ltd.
Chicago, Illinois

**CHRIS JOHANSEN**
Victor Adding Machine
Chicago, Illinois

**R. W. KELEHER**
Wyman Gordon
Harvey, Illinois

**JOHN K. RILEY**
H. H. Cross Co.
Chicago, Illinois

**HERBERT T. STANNER**
Viscosity Oil Co.
Chicago, Illinois

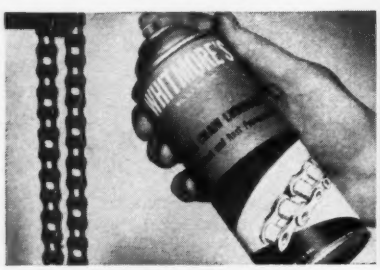
**CHALMER V. WEISSERT**
U S Steel—Gary
Sheet & Tin
Gary, Indiana

**JOHN R. BREHMER**
Stewart-Warner Corp.
Chicago, Illinois

**NICHOLAS MAZURANE**
Allis-Chalmers
Harvey, Illinois

**Reinstatement*


# TRIAL SAMPLES
## *Of World-Famous WHITMORE'S Lubricants*




**OPEN CHAIN LUBRICANT INCREASES CHAIN LIFE UP TO 300%**

Penetrates, lubricates, prevents rust. Lubricates deep into chain linkage to reduce friction on pins, rollers, bushings, pressure surfaces. Corrosion inhibitor prevents rust in vital working mechanisms. Lubricates close-tolerance internal surfaces to increase chain life up to 300%. Highly recommended for all climatic conditions to stop rust and corrosion even in salt atmospheres.

Packaged in handy 16 oz. aerosol spray-on containers or in bulk — send for a free trial sample.

**ANTI-FRICTION COMPOSITIONS HAVE NO MELTING OR DROPPING POINT**

Packaged in 14½ oz. cartridges for handy application with lever-type cartridge guns for constant protection to roller, ball, sleeve bearings and sliding surfaces in "hot" bearing applications or in areas with high ambient heat. Exclusive formulas have no melting or dropping point; moisture resistant; will not wash out; exceptional metal adherence properties; temperature reducing qualities; high extreme pressure values. Available in two grades. Whitmore's Anti-Friction Composition No. 1 (light density), recommended for high speed, high temperature applications. Anti-Friction Composition No. 2 (heavy density), for low-speed high-temperature applications or loosely-fitted bearings. Specify No. when requesting free trial sample.

**68 YEARS OF LEADERSHIP LUBRICATING THE FOLLOWING:**

- Open Gears, Dipper Sticks, Cams
- Open and Enclosed Chain
- Speed Reducers
- Enclosed Gear Cases
- Roller, Ball and Sleeve Bearings
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LUBRICATING ENGINEERS
CLEVELAND 4, OHIO • VULCAN 3-7272


## A MOMENT OF REFLECTION . . .

**Paying** your membership dues is one way of supporting ASLE . . . its programs . . . its activities. **Participating** in the programs and activities of the Society . . . designed for your benefit . . . is another. **Procuring** a new member who is interested in the science of lubrication and the work of the Society is still another . . . These three P's represent what is needed of members to make ASLE the organization it has a right to be.

## PERSONALS

**Dr. A. B. Wilder,** Chairman Presidential Council, ASLE, has been transferred from the Chicago office of E. I. du Pont de Nemours Co. to the Wilmington, Delaware office.

Mr. Charles P. Orr, President, Spray Products Corporation, announces the appointment of **Kenneth B. Owings** as Manager, Engineering. Mr. Owings will be responsible for design and development of the company's products.

Pall Corporation, Glen Cove, N.Y. announced recently the appointment of **Joel J. Shulman** to the newly created position of Public Relations Manager.

The appointment of **Walter H. Shealor** as Assistant Director of Sales, International Divisions of The Timken Roller Bearing Company has been announced.

C. Neil Norgren, Executive Vice President of C. A. Norgren Co. announced the appointment of **William O. Hall** as Chief Engineer. C. A. Norgren Co. manufactures pneumatic products with plants in Englewood and Littleton.

The Atlantic Refining Company has announced the appointment of **H. B. Elliott** as manager of the industrial products division in the firm's special "Sales" department.

**L. M. Tichvinsky,** Professor of Mechanical Engineering, University of California, Berkeley, California is on leave during the 1960 Fall Semester. Until February 1961, he is with the French Petroleum Institute in Rueil Malmaison (S. & O.), where as a Fulbright Lecturer, he conducts a course on Bearings, Friction, Lubrication and Wear.

The board of directors, Battenfeld Grease and Oil Corp., Inc., has announced the election of **Hugh H. Bruner** as President, and Chief Executive Officer of the company.

A new sales representative, **Henry J. Lang,** has been appointed to the Western Pennsylvania-West Virginia area for Acheson Colloids Company, Port Huron, Mich. The area office is located at 530 Sixth St., Pittsburgh 19, Pa.


# Plan to attend the ASLE Annual Meeting and Lubrication Exhibit at The Bellevue Stratford Hotel • Philadelphia, Pa.

## April 11-12-13, 1961

### HOTEL RESERVATIONS

Complete this reservation form and mail to the address shown stating "ASLE Annual Meeting."

**The Bellevue Stratford • Broad and Walnut Streets • Philadelphia, Pa.**

Please reserve:

Single..... Double..... Twin..... Studio..... Suite ..... Unit.....

at $ per day, for Arrival.....time.....m

I will check out.....time.....m

DAILY ROOM TARIFF

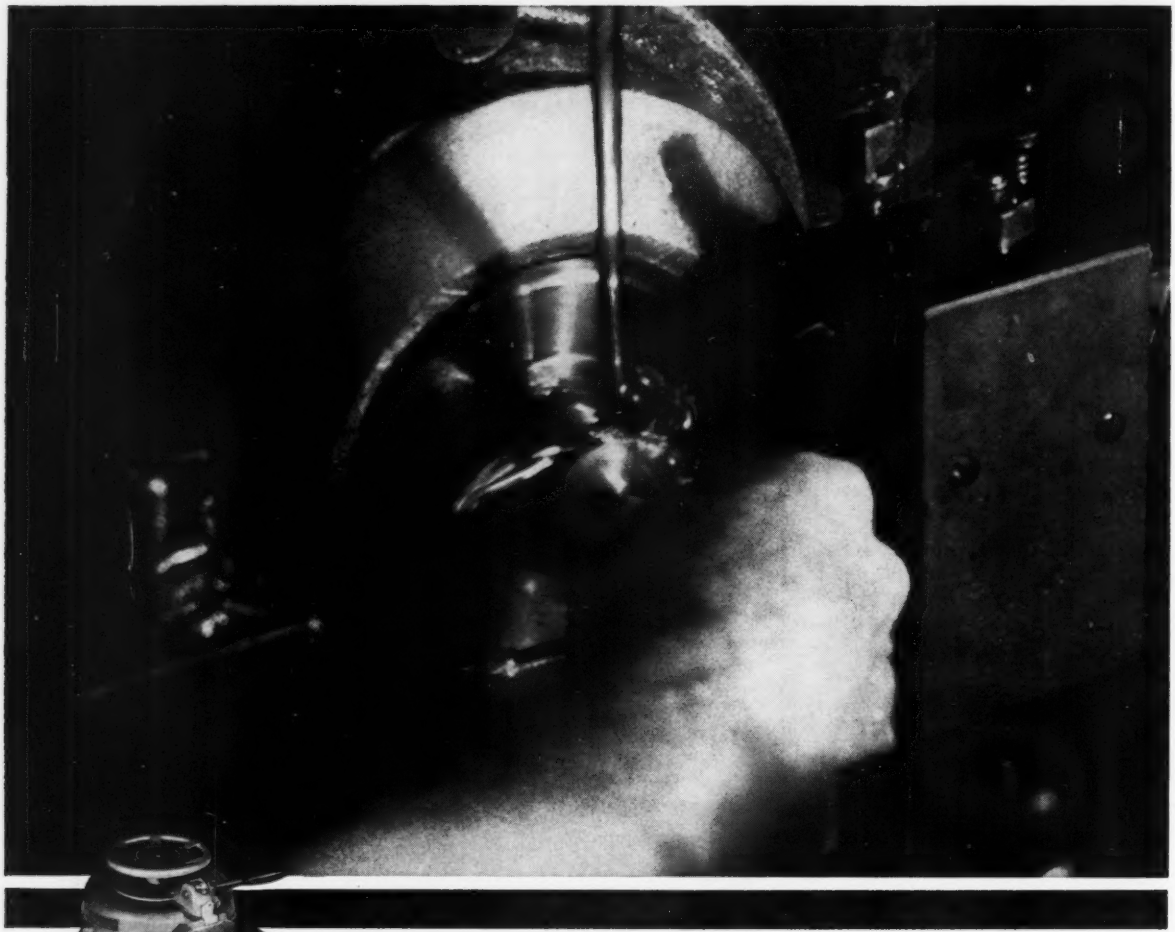
| | |
|---|---|
| Single Room and Bath | $ 9.50 to 14.50 |
| Double Bed, Room and Bath | $15.00 to 19.00 |
| Twin beds, Room and Bath | $15.00 to 20.00 |
| Suite (Parlor, twin bedroom and bath) | $30.00 to 55.00 |
| Unit of two twin bedrooms and bath between: 2 persons 18.00 3 persons 21.00 4 persons 25.00 | |

If a room is not available at rate requested, reservation will be made at the next available rate. Reservations must be received not later than 2 weeks prior to the opening date of convention and will be held only until 6 p.m. on day of arrival unless later hour is specified.

Name (please print).....

Address .....

City ..... Zone ..... State .....



# COOL CUTS

Keeping close tolerances is of prime importance at Diagraph-Bradley Industries, Inc., of Herrin, Illinois, leading manufacturer of stencil machines and accessories. One of the ways this is accomplished is by keeping cutting edges cool.

At Diagraph-Bradley stencil punches must be cut and held within .0005 of an inch—a fine point of precision Diagraph-Bradley attributes to the cooling and lubricating effect of Cities Service Chillo 10 cutting oil.

"You have only to take a Diagraph-Bradley machine," says one of the company officials, "cut a stencil with it and look at the resulting letter to realize how important the right cutting oil is to our production."

Cities Service Chillo 10 oil is a sulphochlorinated oil. The concentrations of sulphur and chlorine are stabilized by a special process, assuring uniformity of action through the entire cutting operation.

That's why, with Cities Service Chillo 10 cutting oil, work is always more accurate, clean and cool!

For full information call your nearest Cities Service office or write Cities Service Oil Company, Sixty Wall Tower, N.Y. 5, N.Y.

**CITIES SERVICE**

QUALITY PETROLEUM PRODUCTS

Vol. 17, No. 1

Lubrication Engineering

**why do we need more members?**

. . . is purely a matter of sound economics and is not motivated by greed, or the desire to enter into a statistical race.

As a member of ASLE, let us examine for a moment what MORE members means to *you*. Production cost of LUBRICATION ENGINEERING (not including salaries, overhead, etc.) amount to roughly 50¢ per copy, based on a run of 6,000 copies. This means that about 33% of your annual dues is allocated for the publication of this journal. Now, let us assume that we had a run of 3,000 additional copies (9,000 total)—the per copy cost would be reduced to 35¢, or 21% of your annual dues. Carrying this a little further, assume that the run is 12,000 copies, the per copy cost is further reduced to 30¢, or 18% of your annual dues.

BUT THIS IS NOT ALL—let us consider the attraction to current and prospective advertisers of an engineering magazine with a circulation of 6,000 copies as opposed to one with a circulation of 9,000 or 12,000 (assuming, of course, that high quality reader standards are maintained). Advertisers and their agencies would surely welcome the opportunity to get their message to additional influential people in the field of lubrication, who are not now reached in LUBRICATION ENGINEERING. And what is important to you as a member is that advertisers are willing to pay for it. As the circulation grows—so grows the advertising page rate! As the advertising page rate and the number of advertisers grow—so grows the revenue of the Society! A vicious circle—yes. And it can be cut into by showing a gain in our membership column.

What does all of this mean to you—a member? A great deal, of course. It means very simply, the lower the percentage of your annual dues applied to LUBRICATION ENGINEERING costs, the greater the percentage that can be applied to other programs of the Society. Programs that can be of tremendous help to you. More simply stated—you can get more for your dues dollar—and we are sure that this is what everyone wants.

This philosophy could be carried to other publications and activities of the Society, such as the ASLE TRANSACTIONS and the Lubrication Exhibit (held at the time of our annual meeting). More members would undoubtedly mean more subscribers to the TRANSACTIONS, thereby lowering the unit cost. More members would undoubtedly mean a larger attendance at our annual meeting, thus increasing the value of the exhibit spaces. So on, *ad infinitum*.

Mind you now, all of this member increase can be handled with very little additional cost to the operations of the national office. The staff effort required to publish 12,000 copies of LUBRICATION ENGINEERING is the same as for 6,000 copies. The same situation applies as far as the ASLE TRANSACTIONS is concerned and also for the Lubrication Exhibit.

The answer to the question, "Why Do We Need More Members?" is this: to do a better job for you, the member, and to give you more for every dollar of dues that you pay as a member of the Society.

With these thoughts in mind, why not resolve in 1961 to do your part in obtaining new members, so that ASLE can more effectively serve you?

**L. O. Witzenburg**
**President, ASLE**

*Laboratory Evaluation of*

# Automotive Gear Lubricants

by S. R. Calish, Jr.
California Research Corporation,
Richmond, California

**A series of laboratory tests which predict the service performance of automotive gear lubricants is described. The tests have been selected because of their correlation with service experience in heavy-duty equipment in the Western States. A comparison is made between oils of the old MIL-L-2105 type and the new, high activity MIL-L-002105A oils. Laboratory test data are given for seven lubricants, all using the same base stock; and field experience with some of these oils is related. Test criteria are suggested for an outstanding multipurpose automotive gear lubricant.**

## INTRODUCTION

Recent advances in automotive design have made it possible for heavy-duty equipment to move heavier loads at higher speeds than ever before. Frequently, this is accomplished by coupling larger engines to already overburdened gear boxes without regard to the effect on gear or lubricant life. High-speed truck operation often requires the use of lubricants having the antiscore protection of passenger car hypoid gear oils. In trucks, however, the other important lubricant properties cannot be sacrificed in order to achieve this goal.

Because a single drain interval for a truck may represent the total life of a passenger car, the effect of many lubricant properties other than gear tooth surface protection must be determined. In heavy-duty service, the following gear lubricant properties are considered important:

1. Wear protection
2. Load carrying capacity
3. Stability
   a. Oxidative
   b. Thermal
4. Corrosion protection
   a. Rust
   b. Chemical
5. Low temperature fluidity
6. Antifoaming

Most of these properties are also significant in passenger car service, but the emphasis on long lubricant life need not be stressed to the same degree.

The technology in this field has been changing rapidly, both from the formulation standpoint and in regard to new methods of evaluation. Some of the most recently developed test methods have permitted precise designation of the performance level of automotive gear lubricants with regard to load carrying capacity or antiscore protection. To a lesser degree, the precision with which a gear lubricant may be evaluated for wear, corrosion, and stability has also been improved. Unfortunately, service correlation with these latter procedures is not yet well established, and they are complicated and expensive to run.

## LABORATORY EVALUATION

A series of laboratory bench and machine tests is used to evaluate new automotive gear lubricants. Some of the test methods were developed in the author's laboratory; others have been disclosed in the literature and were only slightly modified to suit our requirements. The complete test sequence provides a good

Presented at the 15th ASLE Annual Meeting in Cincinnati, Ohio
April, 1960

over-all evaluation of potential multipurpose gear lubricants, especially after some experience has been acquired through testing of reference oils of known service performance.

In the following portion of the paper each test procedure is described and the anticipated levels of performance for typical gear lubricants are indicated. Suggested ranges for a satisfactory multipurpose gear lubricant for today's passenger cars and trucks will also be given. All of the gear lubricants given as examples were blended with the same base oils.

## WEAR PROTECTION

The introduction of the hypoid gear in trucks soon demonstrated that very active extreme pressure (EP) type passenger car hypoid gear lubricants could not be tolerated in the lower speed, high-torque truck service. Gear teeth and bearings showed excessive chemical wear without any sign of scuffing or welding associated with insufficient lubricant load carrying capacity.

Through cooperative effort in the Coordinating Research Council, two dynamometer axle tests were devised which would pass oils having the proper balance between EP activity for high-speed, shock load protection, and antiwear properties for the high torque conditions. This development marked the transition from U.S. Army Specification 2-105A to 2-105B. The latter specification became MIL-L-2105 when joint military procurement policies were adopted.

Shortly after this, S. A. McKee and his coworkers (1), of the National Bureau of Standards, published some interesting data on the wear properties of automotive gear lubricants. They operated the SAE Machine (Fig. 1) at constant speed, load, and temperature, and determined the wear of the cylindrical steel test specimens. Several operating conditions were studied. Careful scrutiny of McKee's data showed that one specific set of conditions gave the greatest difference between overactive and satisfactory oils. The performance of several known gear oils closely approximated test results in the CRC-L-20 axle test (2) and wear in heavy-duty truck service. Fig. 2 shows data from tests conducted by the author's company with typical gear oils.

Early experience with active sulfur-lead soap hypoid gear lubricants and later with U.S. Army Specification 2-105A oils in trucks showed that severe wear occurred rapidly in high-load, low-speed service. Bearings were especially vulnerable to damage, and control of adjustment was soon lost. The typical high wear curves for active sulfur and 2-105A oils are shown in Fig. 2.

The operating conditions selected were:

SAE Machine
500 rpm
3.4:1 Roll Ratio
180 Lb. Load
225 F
500 ml/min. Flow Rate
4 Hours' Test Duration

Early in the development of the new class of materials for use in API Service GL-4 or MIL-L-002105A (Ord.) gear oils, experimental oils were tested in the modified SAE Wear Test. The results shown in Table 1 were obtained in four-hour tests.

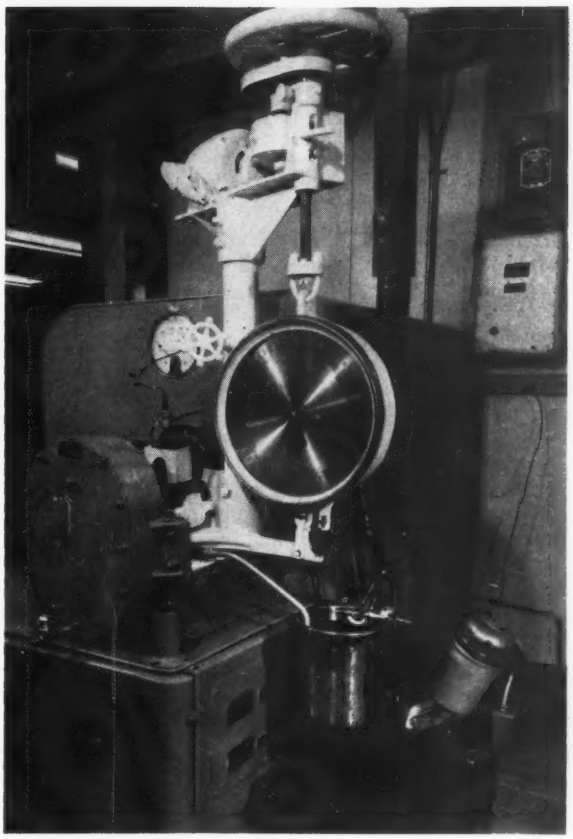


Fig. 1. SAE Wear Test Setup

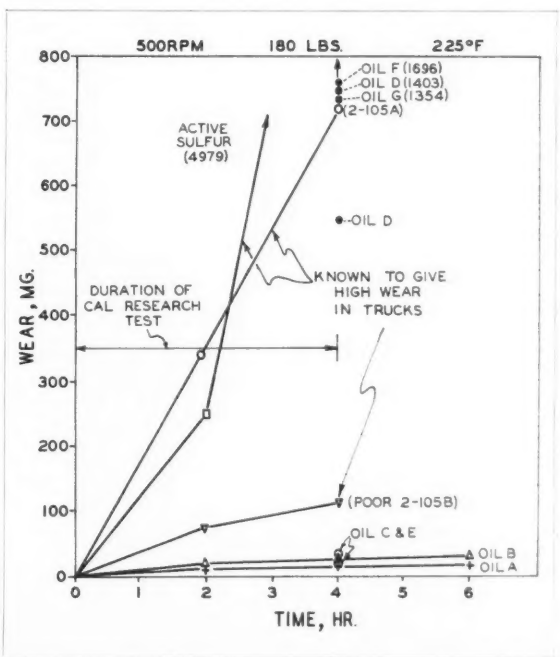



Fig. 2. SAE Wear Test Data

TABLE 1
SAE WEAR TEST RESULTS

| Lubricant | Wt. Loss, mg |
|---|---|
| MIL-L-2105—SAE 90 | |
| Oil A | 4.4–19.0 (12 runs) |
| Oil B | 19.5 |
| Oil C | 28.5 |
| MIL-L-002105A—SAE 90 | |
| Oil D | 548, 1403 |
| Oil E | 22.0 |
| Oil F (Oil D+limited slip fix) | 1696 |
| Oil G (Oil E+limited slip fix) | 1354 |

Over 160 runs have been made in this equipment. Experience in the laboratory and from service indicates that it is desirable to hold the wear to less than 30 mg in this test consistent with other desired oil properties. Some approved MIL-L-2105 oils have SAE Wear Test values approaching 100 mg, but these are not considered desirable for heavy-duty service. Recent failures reported in tractors (3) show what high wear, overactive oils will do.

## LOAD CARRYING CAPACITY

An estimate of the load carrying capacity and shock load protection of gear lubricants can be made from the values obtained in the standard SAE Test at 1000 rpm, Federal Test Method 6501.1 and the Timken Machine Test, Federal Test Method 6505 (4). The SAE Test gives better correlation than the Timken Test with antiscore requirements of axle tests devised by the auto manufacturers to evaluate gear oil performance in new gears. The Timken Machine, due to its test specimen configuration, is more sensitive to viscosity and fatty materials and is related to film strength of lubricants at low speed and high load.

TABLE 2
EP TEST RESULTS

| Lubricant | SAE, lb. | Timken, lb. |
|---|---|---|
| MIL-L-2105—SAE 90 | | |
| Oil A | 150 | 55 |
| Oil B | 245 | 40 |
| Oil C | 200 | 70 |
| MIL-L-003105A—SAE 90 | | |
| Oil D | 500+ | 35 |
| Oil E | 460 | 30 |
| Oil F (Oil D+limited slip fix) | 260 | 35 |
| Oil G (Oil E+limited slip fix) | 260 | 40 |

Off highway, strip mining is an unusually severe test of the load carrying capacity of gear lubricants. In one operation, an oil similar to Oil B was being used. Second reduction gears of large, 50-ton truck axles were showing signs of premature wear. The manufacturer specified an oil such as Oil C which had a Timken Film Strength of at least 70 pounds. This oil provided adequate wear protection but soon gave trouble because of poor oxidation stability. Oil A proved to be a better solution. The additive used gave better low-speed, high-load wear than Oil B, as shown by the Timken Machine and at the same time did not cause deposits due to oxidation.

High values are sought in both the SAE and Timken Tests consistent with other desired properties, a minimum of 150 pounds in the SAE and 50 pounds Timken being acceptable. Higher SAE loads would be preferable, but oils which give over 250 pounds seldom possess the all-around performance desired.

## STABILITY

For many years the largest trucks to be found in the United States have been operated in the Western States. Many states in this area permit vehicles of 76,000 pounds gross to operate on highways. In addition, mining and logging industries use large numbers of off-highway vehicles which carry well over 50 tons payload. These rugged operations generate high gear box temperatures. In highway worm-drive service, peak temperatures of 340 F have been measured in rear axles with over 250 F average operating temperatures on SAE 140 grade oils.

As if this were not problem enough, labor costs have forced operators, for economic reasons, to extend drain intervals to coincide with major engine overhauls. Two billion miles of heavy-duty fleet operation were surveyed from 1951 to 1956 (5). The survey shows that two thirds of the truck operators drained differential lubricant at mileages in excess of 40,000 miles. The largest percentage, 33%, changed at engine overhaul. Because heavy-duty fleet use of gear lubricants accounts for a large volume of this product, for some petroleum suppliers as much as 65% of the total, the requirements of truck service determine to a large extent the product sold for multipurpose gear lubricant.

Long service at high temperature imposes a serious stability limitation on the useful life of automotive gear lubricants. The ultimate result of oil deterioration, whether from oxidation or thermal instability, is deposits and viscosity increase. Fresh oil properties should be maintained as long as possible to avoid bearing failures due to clogged oil passages or gear failure because of excessive viscosity and lack of oil feed.

A modification of the ASTM Method D 943-54, "Oxidation Characteristics of Inhibited Steam Turbine Oils," has been used since 1946 to evaluate the resistance of gear lubricants to deterioration due to heat. The test is conducted at 250 F without the addition of water. Viscosity increase at 210 F and insolubles are checked at regular intervals. Excessive sludging or 100% viscosity increase is the criterion of useful lubricant life. Test procedure details are given in Appendix A.

TABLE 3
OXIDATION TEST RESULTS

| Lubricant | Hours to 100% Viscosity Increase at 210 F | Sludge at 200 Hr., % |
|---|---|---|
| MIL-L-2105—SAE 90 | | |
| Oil A | 600–800 | 0.7 |
| Oil B | 350 | 1.0 |
| Oil C | 250 | Over 10 |
| MIL-L-002105A—SAE 90 | | |
| Oil D | 410 | 8.8 |
| Oil E | 330 | Over 10 |
| Oil F (Oil D+limited slip fix) | 405 | 9.6 |
| Oil G (Oil E+limited slip fix) | 460 | 5.6 |

To insure adequate stability to permit long service in heavy-duty equipment, 600 hours minimum for 100% viscosity increase is required in this test. Oils which give more than 2% sludge at 200 hours are also rejected. A wide variation in appearance of the catalyst coils during the test can be observed. Considerable information can be obtained from periodic examination, especially if copper corrosion is encountered. Typical catalyst coils are shown in Fig. 3.

The results from the Gear Oil Oxidation Test have shown excellent correlation with service. An oxidation inhibitor was added to a special automotive worm gear oil on the basis of a predicted 40% to 50% increase in life from Gear Oil Oxidation Tests. A subsequent service test in the worm-drive rear axles of a tank truck fleet confirmed this prediction. The trucks were loaded to 76,000 pounds gross weight and operated throughout the summer in the San Joaquin Valley and desert areas of California. After 35,000 miles of service, the inhibited oil showed only 60% of the viscosity increase of the regular product. These results indicated a 38% improvement in lubricant life.

Limited data also show agreement with the results from the Thermal Oxidation Stability apparatus of the MIL-L-002105A specification. The Gear Oil Oxidation Test procedure has the advantage of simplicity, capability of multiple simultaneous runs; and the equipment is already in use by most petroleum laboratories.

## CORROSION PROTECTION

The introduction of highly reactive chemicals into automotive gear lubricants in the early 1930's opened the door for corrosion problems. The balance between sufficient chemical activity for gear tooth surface protection when needed, and excessive activity, is still difficult to attain. Modern gear oil additives represent a tremendous advance in this technology; however, the fine line remains, and different additives may show wide variations in corrosion tendencies.

Rust protection is important in gear lubricants, especially in those applications where intermittent operation or prolonged idle periods are involved. In these cases, moisture enters the gear case from natural breathing during temperature cycles; and, if adequate rust protection is not provided, machined surfaces of gears and bearings will rust. Antifriction bearings under light load are particularly vulnerable, and several instances of contact bearing corrosion in gear cases have been encountered. This is often the case in agricultural, logging, or contracting equipment in the Pacific Northwest where high humidity prevails.

During an especially severe winter in the Pacific Northwest, the logging industry came to a standstill; and many truck fleets were parked in open lots and were covered with snow. Some water entered the gear cases. When these trucks were restored to service, a rash of rear axle bearing failures was encountered. Inspection of the bearings revealed contact corrosion between the rollers and races of the bearings. A test procedure was devised to simulate this condition in the laboratory. This test is now called the Clamped Bearing Rust Test, and details are given in Appendix B.

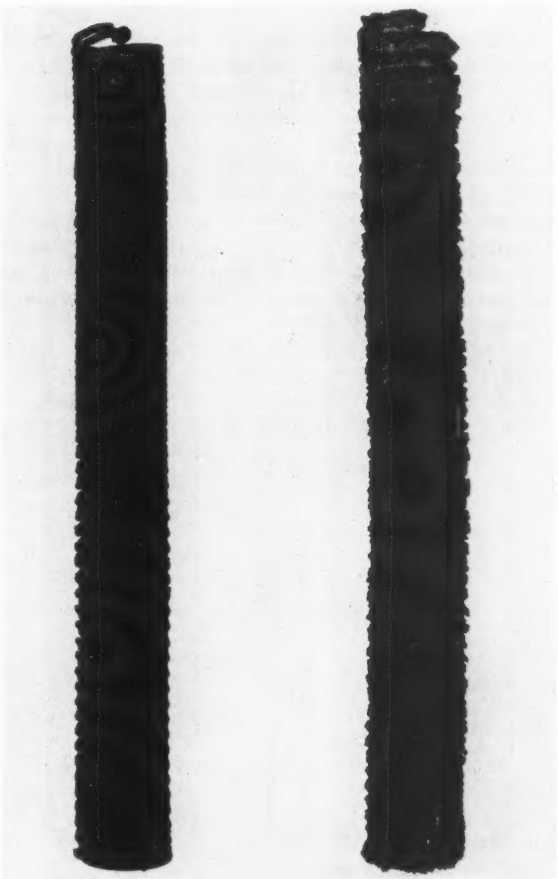


**Fig. 3. Gear Oil Oxidation Test, Catalyst Coils**
**Oil A after 704 hours (left)**
**Oil G after 460 hours (right)**

After conducting hundreds of tests on almost as many oils, a standard set of reference photographs by which to rate results has been compiled. A copy of the ratings is shown in Fig. 4. Oils using the same additive as Oil B (6 rating in test) gave serious trouble in the field. Oil A (rating = 1-2) provided better protection and, if drained and refilled prior to shutdown, was adequate.

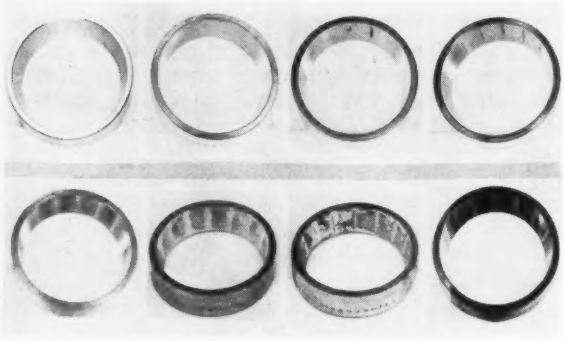


**Fig. 4. Clamped Bearing Rust Test Rating**
**Top: Ratings, 0, 1, 2 and 3**
**Bottom: Ratings 4, 5, 6, and 7**

Several other bench and machine tests have been devised to simulate field conditions where rust has occurred. The Moisture Corrosion Axle Test of Specification MIL-L-2105 was an attempt to control this property. It was not a sufficiently severe test to prevent inadequate lubricants from appearing in service. The Z-19 (6) procedure was an early effort to control the rust preventive properties of EP gear oils. It uses an Almen or Falex Machine to activate the additives in a compounded gear oil, after which the test specimens are stored in a humid atmosphere. They are evaluated after 24 hours for the presence of rust. Each of three areas on the specimens is rated for rust on the basis of 0 = no rust to 4 = heavy rust. The final rating is on a scale from 0 to 12 for heavy rust all over. Fig. 5 shows typical Z-19 test results. Note the difference in appearance in the load bearing area where the dull gray surface on the right hand specimen is actually rust. A similar test has been used by a large axle manufacturer for its recommended multipurpose gear oils (7). These procedures have the advantage of simplicity and use lubricant which has been subjected to elevated temperatures.

Both the Z-19 procedure and the Clamped Bearing Rust Test are now used to evaluate the rust protection afforded by gear lubricants. Values for the typical gear lubricants under consideration are:

TABLE 4
RUST TEST RESULTS

| Lubricant | Rust Test Ratings | |
|---|---|---|
| | Z-19 | Clamped Bearing |
| MIL-L-2105—SAE 90 | | |
| Oil A | 2–4 | 1–2 |
| Oil B | 8 | 6 |
| Oil C | 0–2 | 0–1 |
| MIL-L-002105A—SAE 90 | | |
| Oil D | 2–4 | 1–2 |
| Oil E | 6–10 | 3 |
| Oil F (Oil D + limited slip fix) | 7 | 1–2 |
| Oil G (Oil E + limited slip fix) | 3 | 1–2 |

About 80% of the worm-drive axles in operation in the United States are located in the Western States. Their widespread use, plus the use of copper alloys for

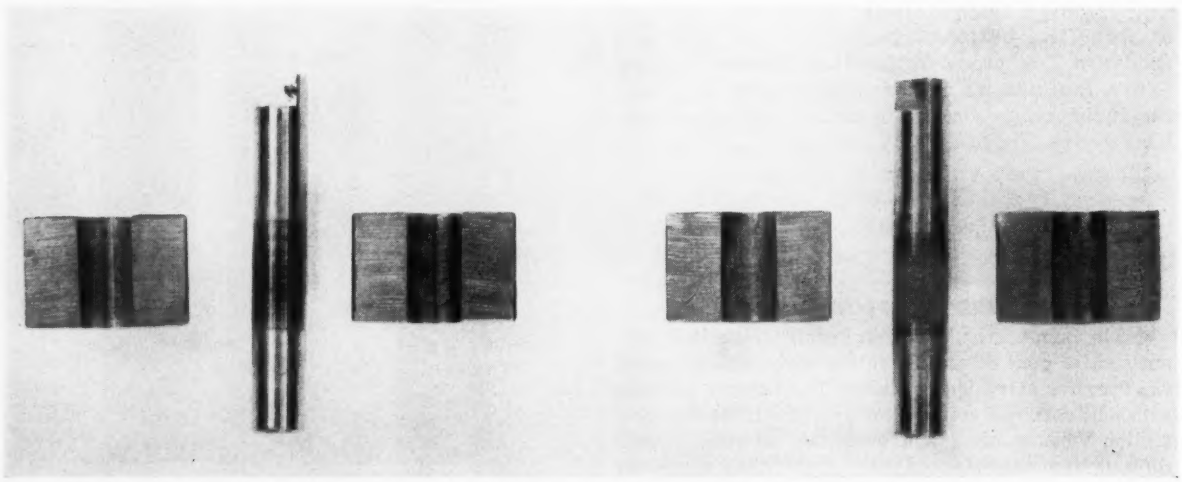


**Fig. 5. Z-19 Rust Test, Almen Machine**

**Oil A, Rating 1 (left)** **Oil F, Rating 9 (right)**

thrust washers, differential spider bearings, and bushings in many gear cases, has required close control of chemical activity toward brass and bronze. Many truck fleets have both hypoid and worm-type axles in operation. A special lubricant for each axle type is undesirable for both economic and maintenance reasons. Proper selection of a multipurpose gear lubricant permits the use of a single lubricant for the entire fleet.

A simple copper strip test, one hour at 250 F, is used to control reactivity toward copper alloys. This eliminates only the very corrosive oils. A heavy duty axle manufacturer employs a bench test using actual gear bronze for this purpose. Their procedure, the Bronze Corrosion Test (7), is probably more severe as microscopic examination of the SAE 64 bronze specimens is prescribed.

Experience has shown that actual performance tests in worm-drive axles are required to evaluate this property of gear lubricants. That copper alloy corrosion is not predicted from simple copper strip tests is attested by the fact that all the gear lubricants meeting both the old and new military specifications pass such a test, but their performance in worm drives and in gear cases using bronze bearings differs widely. Only limited experience has been obtained with TDA's procedure.

## LOW TEMPERATURE FLUIDITY

Low temperature fluidity of automotive gear lubricants is important from two aspects. The oil must be readily dispensed from containers. The oil must also flow readily in the gear case so that it may be carried by the bull gear to the many bearings, shafts, and spider gears depending on this oil supply. The ASTM pour point is a fair measure of the ability of an oil to pour from a barrel bung. Unfortunately, cycling temperatures often cause variations in the apparent pour points of lubricants. Several so-called "stable pour point" procedures have been developed. At Cal Research several stable pour surveys have been conducted. Samples of lubricants have been shipped to locations where ambient temperatures vary widely so that regular observation of the pour characteristics may reveal the effect of temperature cycles (8). These results have been translated into laboratory test cycles. Gear oils intended for use in the Pacific Northwest and Alaska are tested for stable pour points.

The widest daily ambient temperature variations in the United States are encountered in the Western States. Vehicles can leave the coastal regions in the morning where temperatures are in the 60's, travel through valleys and deserts at 100 F, and at night be parked in the open at below freezing temperatures in the Mountain States. For this reason, the lubricant grade selected must be a compromise. The SAE 90 grade has proved very satisfactory provided its channel point is maintained sufficiently low. The Channel Point Test as prescribed in the military gear lubrication specification (Federal Method 3456) is satisfactory for production control purposes but gives little information on the effect of additives on the low temperature fluidity of base oils.

The old channeling characteristics test of the VV-L-761 Universal Gear Lubricant specification is used. In this test the sample is cooled to within 20 F of the anticipated channel point at a given rate and then checked for channel point in 5 F increments until channeling occurs. This method is obviously more useful for experimental purposes. Typical channel and pour points for some of the oils described in this paper are as shown in Table 5.

TABLE 5

LOW TEMPERATURE TEST RESULTS

| Lubricant | Channel Point, °F | ASTM Pour Point, °F |
|---|---|---|
| MIL-L-2105—SAE 90 | | |
| Oil A | − 5 | +10 |
| Oil B | −10 | 0 |
| Oil C | −20 | −5 |

## FOAMING

The ASTM Foam Test (Method D 892-46T) was designed to determine the foaming tendency of crankcase oils. It has not been found suitable for gear lubricants, primarily because it does not simulate the splashing action of gears immersed in high viscosity lubricants.

The present Foam Test, Appendix C, is used to evaluate the foaming tendency and foam stability of automotive gear oils. It effectively simulates gear action and determines whether the small amount of foam formed will persist long enough to contribute to further foaming. The effect of foam stability was forcibly brought home in a transmission foaming complaint from a Texas truck fleet. It was found that the lubricant used passed the control foam test then applicable to gear oils. While the volume of foam formed was within specification limits, it persisted for days. If the sample were retested, an equal volume of additional foam formed; and it would not pass the test. This is what happened in service. The volume increased incrementally until bearing and seal failures occurred. Additional foam inhibitor corrected the situation.

Silicone defoamers were of great benefit in permitting crankcase oils to pass the ASTM test. Some silicones, in the correct quantities, are used to meet Foam Test requirements. The greatest current foam problem is the transient nature of silicone defoamers. While they may be adequate in fresh oil, newly compounded, they tend to adhere to metal surfaces or are otherwise lost from the system. The majority of field foam complaints can be traced to unused lubricant which was satisfactory when blended but has lost its defoamer in storage and handling.

All experimental oils evaluated in the author's laboratory are adequately defoamed prior to further testing. The oils considered in this paper pass the Foam Test of Appendix C.

## PERFORMANCE REQUIREMENTS

The following performance levels have been found suitable to describe an SAE 90 multipurpose gear lubricant for heavy-duty service in the Western States:

| TEST PROCEDURE | |
|---|---|
| SAE Wear Test, Weight Loss, mg | 30 max. |
| SAE Load Carrying Capacity, lb. | 150 min. |
| Timken Film Strength, lb. | 50 min. |
| Gear Oil Oxidation Test | |
| Hours to 100% Viscosity Increase | 600 min. |
| Per Cent Sludge at 200 Hours | 2 max. |
| Z-19 Test Rating | 4 max. |
| Clamped Bearing Rust Test Rating | 2 max. |
| Copper Strip, One Hour at 250 F | pass |
| ASTM Pour Point, °F | +10 max. |
| Channel Point, °F | 0 max. |
| Foam Test | pass |

## CONCLUSIONS

The requirements for a multipurpose gear lubricant for both passenger car and heavy-duty fleet service emphasize the need for long lubricant life and maximum protection for gears and bearings. While these requirements apply to both types of vehicles, the needs of heavy-duty service are more important because this service represents a large volume of lubricant subjected to critical evaluation by the consumer. After a break-in period of 5000 miles or more, passenger cars operate very satisfactorily on lubricants designed primarily to suit the needs of heavy-duty service.

A sequence of laboratory tests has been suggested for preliminary evaluation of potential multipurpose gear lubricants. Correlation of these tests, or any simple bench tests, with actual axle performance tests or field experience is not perfect. The use of lubricants of known service performance as reference oils is recommended. With these oils and a background of service experience, it is possible to evaluate gear lubricants in the laboratory and to predict their suitability as true multipurpose gear lubricants.

It is the author's opinion that gear lubricants designed to emphasize antiscore protection at the expense of other vital lubricant properties will not meet the suggested performance level requirements. They also cannot be considered true multipurpose gear lubricants but should be called "hypoid gear lubricants."


## ACKNOWLEDGEMENTS

The author wishes to acknowledge the contribution of of F. A. Christiansen of California Research Corporation who pioneered the work with the Gear Oil Oxidation Test, and the assistance of J. M. Bell and R. D. Clouse of California Research in conducting tests and compiling data.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## APPENDIX A

### Procedure for Gear Oil Oxidation Stability Test at 250 F with Copper-Iron Wire Catalyst

*Purpose of Test*

To determine oxidation stability of gear lubricants. Refer to ASTM Standards on Petroleum Products and Lubricants (1953) (D 943-53T). All apparatus, materials, and procedures comply to above specification except where noted below.

*Description of Apparatus*

1. A suitable pyrex glass bath
   a. Thermostatically controlled to 250 F ± 0.5 F.
   b. Stirring device to provide uniform temperatures.
   c. Large enough to hold eight oxidation cells.
2. Oxidation Cell (45 mm diameter, 600 mm long)
   a. Oxygen delivery tube (Shell type).
   b. Mushroom condenser.
3. Flowmeter
   a. Capacity of 4 liters per hour.
4. Oxygen Supply
   a. Suitable pressure regulating mechanism.
5. Catalyst
   a. Armco Iron wire (0.064-inch diameter) No. 14 AW gage
   b. Electrolytic copper wire (0.064-inch diameter) No. 14 AW gage.
   c. Mandrel for forming coils.

*Preparation*

1. Catalyst coil prepared same day as needed
   a. Clean 3000 mm length of iron wire and equal length of copper wire with cotton wet with Precipitation Naphtha followed with polishing with No. 2/o Garnet cloth. Wipe clean with cotton, being careful not to touch with hands.
   b. Wind both wires simultaneously on mandrel through clean cotton ahead of die.
   c. Twist iron and copper together at ends for approximately six turns.
   d. Stretch catalyst coil to sufficient length to reach to within ½ inch below the oil level in the tube.
2. Oxidation Cell
   a. Rinse three times with distilled water.
   b. Drain and rinse with acetone.
   c. Drain and air dry—do not use air hose.

*Procedure*

1. Setup
   a. Slide catalyst coil over oxygen delivery tube and place in oxidation cell.

b. Pour in 300 ml of oil sample and slip condenser over oxygen delivery tube.
c. Place assembled cell in oxidation bath and connect to oxygen and condenser water supply lines.
d. Start test by starting oxygen flow when sample reaches 250 F.

2. Running

The test duration is based on the viscosity increase (viscosity at 210 F) and is normally run to a 100% viscosity increase.

a. Draw approximately 15-ml samples at requested intervals and note condition of catalyst coil.
b. Strain samples for viscosity determinations by gravity through 100-mesh screens.
c. Heat oils on hot plate to aid straining these thick oils.
d. Return excess sample from pipette to oxidation cell.
e. Measure viscosities of samples.
f. At 200 hours, draw sample for sludge analysis.

3. Observations to be made

a. Plot per cent viscosity increase measured at 210 F.
b. At 200 hours, obtain per cent sludge on sample.
c. At end of test, wash catalyst coil in Precipitation Naphtha.
d. Note condition of catalyst coil and compare with standard.
e. Determine isopentane and benzene insolubles of remaining oxidized oil.

### *Rating*

1. Oxidation stability of the sample is rated according to the length of time elapsed to 100% viscosity increase and the amount of insoluble sludge (pentane insolubles) formed at 200 hours.

NOTE: Sludging may proceed at such a high rate that it is not possible to run to 100% viscosity increase. In this case, report the shorter time as useful life of sample.

## APPENDIX B
## Procedure for Clamped Bearing Rust Test

### *Purpose of Test*

To determine the ability of gear lubricants to prevent corrosion of ferrous surfaces in contact under light load. This method is designed to correlate with storage rusting occurring in automotive gear cases when vehicles are idle.

### *Description of Apparatus*

1. 1000-ml beakers.
2. Timken cone No. 15118.
3. Timken cup No. 15250.
4. Stainless steel clamp designed to maintain cone and cup assembled under light load.
5. Six-inch watch glasses.
6. Suitable beater.
7. Oven set at 125 F.

### *Preparation*

1. Test specimens—clean cones, cups, and clamps thoroughly in dry petroleum solvent. Maintain in desiccator until ready to use. Handle only with clean tongs.

### *Procedure*

1. In a 1000-ml beaker, thoroughly mix 300 ml of lubricant and 60 ml of distilled water at the highest speed on the mixer.
2. Using tongs, dip the bearing cone and cup in the mixture, covering all surfaces.
3. Assemble the bearing and clamp together with stainless steel clamp.
4. Stand assembly on OD of cup in lubricant-water mixture in the beaker.
5. Cover with watch glass.
6. Place in oven at 125 F for one week.

### *Observations and Rating*

1. At the conclusion of one week's storage at 125 F, disassemble the bearing and report the following:
   a. Extent of rust on cone and cup.
   b. Degree of emulsification of lubricant.
2. Photograph the race portion of the cup and compare with a standard reference.

## APPENDIX C
## Method 85-17 Foaming Test of Lubricants

### *Scope*

This method is designed for testing gear lubricants and gear oils to determine whether sufficient foam inhibitor has been added to prevent foaming in service. It is not a quantitative test, i.e., it will show whether sufficient foam inhibitor is present but not the amount.

### *Outline of Method*

Approximately 250 ml of sample is stirred in an 800-ml beaker in a mechanical mixer at 650 rpm for 5 minutes. Samples of SAE grade 90 or lighter are stirred at room temperature; samples heavier than SAE 90 are stirred at 125-135F. After standing periods of 1 minute and 5 minutes, the foam is judged as being passable or excessive. A passable foam indicates that sufficient inhibitor is present.

### *Apparatus*

Suitable kitchen type mixer.

### *Procedure*

Adjust the temperature of the samples as follows:

| *SAE Grade* | *Temperature, °F* |
|---|---|
| 90 or less | 75-85 |
| Above 90 | 125-135 |

Pour the sample into an 800-ml beaker to a height of 1½ inches. Attach the paddles to the mixer and lower them into position in the center of the beaker within ⅛ inch of the bottom. Hold the beaker firmly by means of a clamp to prevent moving. Maintain the temperature within the limits given above throughout the test, using a hot plate for the 125-135 F range.

Stir the sample for 5 minutes, maintaining a speed of 650 ± 50 rpm. Raise the paddles from the oil and allow to drain for 15 to 30 seconds. Allow the sample to stand at the temperature specified above to allow the foam to collect on the surface of the oil. At the end of 1 minute after the expiration of the stirring period, measure the height of the foam on the side of the beaker, and note whether it is ¼ inch or less. At the end of 5 minutes, observe whether or not the foam layer on the surface of the oil is continuous.

If the amount of foam is borderline so that doubt exists as to the presence of an adequate amount of foam inhibitor in the sample, repeat the test of the sample, followed immediately by a similar test of a sample of the same type and grade known to be satisfactory.

*Report*

Report "Passes" if the layer of foam at the end of the first minute is not more than ¼ inch thick and if at the end of the fifth minute the layer of foam is not continuous over the entire surface of the oil. If either one of these conditions is not met, report "Foam Excessive."

## DISCUSSION

**by R. K. Smith**
**The Elco Lubricant Corp., Cleveland, Ohio**

The California Research Corporation is to be commended for taking advantage of an excellent opportunity to observe gear lubricants in service under extremes of temperature, humidity, and load; that they have made the most of this opportunity is evident from the data shown in the paper and the well planned program for laboratory testing of gear lubricant materials.

We agree that the Timken and SAE test procedures can be used as an indicator of torque carrying capacity in heavy duty axles. We also concur with the use of the 250 F laboratory oxidation test which is capable of predicting field performance in an environment which resembles field service.

## DISCUSSION

**by R. E. Osborne**
**General Motors Research Lab., Detroit, Mich.**

Mr. Calish has presented bench test data on a series of gear lubricants of the MIL-L-2105 and MIL-L-002105A types. We have some additional data on a gear lubricant that we have been led to believe will pass the bench tests Mr. Calish has mentioned. Also, we have been told that this product is available commercially and further that it is labeled "API Service GL-4."

The test used in our work has been recommended by many of our company divisions to be used to determine the minimum performance level of service gear lubricants. In addition, this test has been submitted to the ASTM Committee B, G-4 Subcommittee on Performance Definition of GL-4 Gear Lubricant.

The test procedure is shown below.

**ROAD TEST PROCEDURE NO. 10-A**
**(Modified for Service Gear Lubricant)**
**REAR AXLE OIL SCORING TEST**

Install new differential assembly and test lubricant. Break in new assembly for 1000 miles of moderate operation. Discard lubricant and inspect gears for evidence of distress. If none is apparent reinstall differential assembly with new portion test lubricant and perform following test schedule:

1. Warm-up car for 5 laps of track at not less than 40 or more than 50 mph. Avoid hard acceleration.
2. Test for drive and coast noise at all speeds up to 75 mph.
3. Make 10 accelerations from 60 to top speed, open throttle, then decelerate to 60, throttle closed. These are to be continuous.
4. On straightaway from a stop, set brakes, open throttle in Low, release brakes and accelerate to 50 mph shifting at about 30 mph. With throttle closed, let car coast to 35, then downshift from Drive to Low. Stop and repeat, going to 60 with downshift at 45. Repeat again going to 70 with downshift at 55.
5. Repeat item 3.
6. Repeat item 2.
7. Remove test member and inspect for indications of scoring.

If noise develops at any point in test, stop test and inspect gears. If scored, discontinue test, reporting stage reached when scoring occurred.

This test has been described as simulating the "normal severe abuse that a customer will give to his car."

The lubricant mentioned previously, labeled for API Service GL-4, has been evaluated using this test procedure. Bear in mind that service gear lubricant should pass this test with a minimum of gear tooth surface distress in the best judgment of rear axle engineers in our company.

Figs. A1 and A2 show the results of the test. Fig. A1 shows the pinion gear. The upper portion of this figure is a view of the drive side of the gear teeth showing only slight distress. The lower portion of this figure is a view of the coast side of the gear teeth. As one can see, scoring is evident over practically the entire contact area. Fig. A2 shows the same views of the ring gear. Here again there is only slight distress on the drive side, but about 90% scoring on the coast side of the gear.

This gear set was, to say the least, not commercial from a noise standpoint under either "coast" or "float" driving conditions.

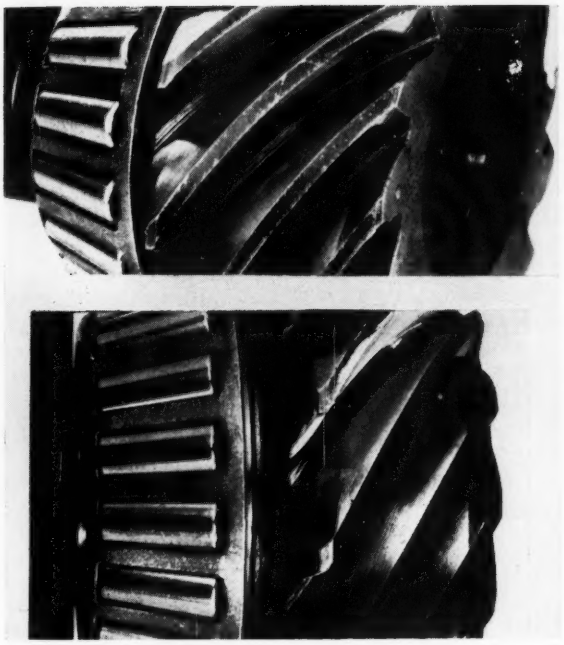

Fig. A1. Pinion Gear after 1,000 mile Break-in. (Top) Drive side (Bottom) Coast side

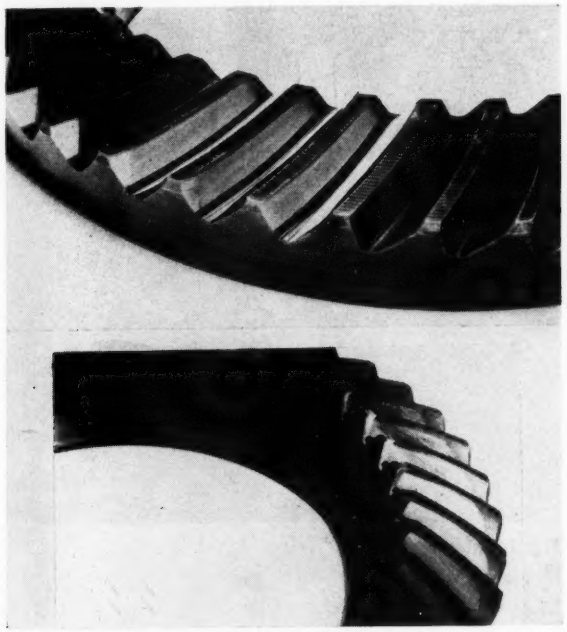

Fig. A2. Ring Gear after 1,000 mile Break-in. (Top) Drive side (Bottom) Coast side

Mr. Calish stated, "After a break-in period of 5000 miles or more, passenger cars operate very satisfactorily on lubricants designed primarily to suit the needs of heavy-duty service." We note that Mr. Calish did not support this conclusion in the body of his paper, however it might be of interest to repeat the test just described using a 5000-mile break-in instead of a 1000-mile break-in.

In the Introduction of the text, Mr. Calish stated, "High-speed truck operation often requires the use of lubricants having the antiscore protection of passenger car hypoid gear oils." Based on the results we have obtained it appears that the lubricant we tested does not have the antiscore protection needed in passenger car hypoid gear oil in the judgment of rear axle engineers in our company.

## AUTHOR'S CLOSURE

I would like to thank Messrs. R. K. Smith and R. E. Osborne for their comments on the paper. With regard to Mr. Osborne's discussion, I would like to correct two false impressions that have apparently been created in private discussions with Mr. Osborne and his co-workers. In the first place, the gear lubricant alluded to in the first paragraph of his discussion is not labeled "API Service GL-4" and never has been. Because this service designation is highly ambiguous, and emphasizes antiscore protection at the expense of "other desirable properties," there has been no advantage in so labelling products.

Secondly, in the passenger car test reported by Mr. Osborne, the test lubricant was used for both break-in and subsequent "bump score" testing. It is recognized that the average passenger car rear axle gears as manufactured in the U.S. today require some sort of preconditioning before a typical multipurpose gear oil can be used in them. This preconditioning can be a phosphate treatment as a final step in manufacture or a period of operation on a highly active gear oil during the break-in stage. As these high activity oils are not desirable service station and truck oils, they are not recommended for continuous heavy duty service. Instead, factory fill oils of the active type are used for sufficient time to precondition the gears and then multipurpose gear oils are recommended.

If the test described by Mr. Osborne was conducted in this manner, using factory fill oil for the 1000 miles and then the test oil, very different results may have been obtained. Service station experience has shown that after sufficient break-in on factory fill active hypoid gear oil (as much as 5000 miles may be needed) less active multipurpose oils may be used with complete success. These true multipurpose oils do not sacrifice such desirable properties as thermal and oxidation stability and corrosion protection to achieve load carrying capacity.

THE LUBRICATION OF

# *Rings and Travelers*

## *on Textile Spinning and Twisting Frames*

**by T. M. Murphy**
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**The purpose of this paper is to report to the industry on the advance made in applying extremely small quantities of lubricant to the rings and travelers of spinning and twisting frames used in the Textile Industry.**

**The problem involves a method of conveying the lubricant to the surface of hardened steel rings and the ability to measure small quantities of lubricant approximating .0001 cu. in. quantities.**

**The solution of this lubrication problem has resulted in increased speeds and production on some machines without mechanical modification. On others the solution of the lubrication problem justified the mechanical modification of the machines to the point where they could approximately double speed in production.**

**Many other of the normal advantages of centralized lubrication also were accomplished.**

Probably because every man, woman and child uses clothing or fabric in some form, there is an inquisitive fascination as to how that fabric is made.

The transferring of plant and animal fibers and synthetic filaments into a fabric is also interesting from a historical point of view, in that the methods used constitute one of the records of the social, economic, and technical advancements of civilization.

In conjunction with the Annual Convention Meeting of the American Society of Lubrication Engineers, it is the purpose of this paper to report on the advancements made in the method of lubricating in one phase of the textile manufacturing business; namely, the method of lubricating the rings and travelers on machines called spinning and twister frames. These frames convert plant, animal and synthetic fibers into thread, yarn or cord for weaving.

The raw fibers are cleaned, picked, carded and combed into a long, light, gauze-like ribbon that is folded over into a very light rope-like filament called roving that is wound on a large roll called a creel.

The rolls of roving are introduced to the spinning frame as shown in Fig. 1.

The roving is led into the spinning frame through rollers and shafting and down to the ring, through the traveler and onto a bobbin.

The yarn, held under a specified tension, is twisted and gathered on the bobbin by the rapid rotation of the spindle on which the bobbin is set. The twist is put into the yarn to bind the fibers together and increase its strength.

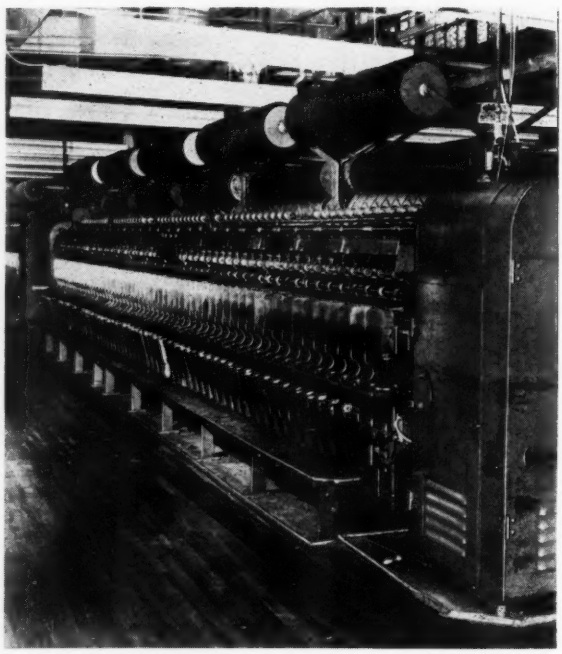

**Fig. 1. Spinning Frame.**

**Presented at the 15th ASLE Annual Meeting, Cincinnati, Ohio, April, 1960**

Sometimes two or more single yarns from a spinning frame are twisted together on a machine called a twister frame and a ply yarn is formed.

Sometimes two or more ply yarns are twisted together and a cord is formed.

For the purposes of the author's discussion, the twister frame looks like a spinning frame.

The ply yarn is stronger than the combined strength of its single yarns, and the cord is stronger than the combined strength of its ply yarns.

One of the major objectives in manufacturing the yarn, the ply, and the cord is the maintenance of uniformity in strength, twist, and cross-sectional area throughout. Any factors of variable or uncontrolled friction in these operations will, of course, affect the attaining of these objectives.

The location at which the greatest variance in friction is likely to occur is where the traveler rides on the ring (Fig. 2).

The traveler fits the ring loosely, but because of the pull of the thread, the high speed up to 10,000 rpm, and the fact that it is a rubbing contact as the travlerer speeds around the ring, considerable friction can be generated. Therefore, the ring on which the traveler rides should have some form of lubrication.

In years past the customary method of lubricating the rings consisted of, first, shutting down or stopping the frame. The operator, or frame tender, would then go up and down the aisle with a small can of lubricant in one hand, and with the fingers of the other hand he would wipe a thin film of the lubricant on the inner surface of each ring of the frame. There are generally from 100 to 200 rings per frame.

After a few minutes for applying the lubricant, the frame would be restored to production. Frequency of this interruption and application of lubricant depends on several factors, such as type of yarn being made, size of ring, weight of traveler, speed of machine, etc.

When one recognizes that there may be several thousand rings in an average textile plant doing spinning and twisting, the downtime and loss of production alone is generally justification enough to consider the application of centralized lubrication methods as a means of overcoming this lubrication problem.

The first barrier encountered, especially on existing rings in the field, is how to conduct the lubricant to the inner surface of a hardened steel ring and do it without creating interference with the thread and traveler that slides around the ring.

Many frames vary in small points, such as cast rails, stamped rails, etc., depending on the manufacturer of the frame. Therefore, the objective is to find a good method that could be most universally adaptable. One method that has been found very satisfactory with respect to universal applicability, easy accomplishment, and economical in cost, is as follows:

The hardened steel ring, as shown in cross-section in Fig. 3, may be drilled at any desired angle with the use of an electron drill, as shown in Fig. 4. Rings may be drilled at the rate of approximately one ring every minute.

The rail section that holds the ring is drilled and slotted, as shown in Fig. 5.

Preparing the rings and rail sections becomes a relatively easy methodical task, when it is realized that there generally are many thousands of rings to be done at one time and the procedure may be set up on a regular production basis right in the operating plant.

After the drilling and slotting work has been accomplished, the centralized system may be applied to the frame in a conventional manner with a measuring ing valve serving each ring, as in Fig. 6.

The measuring valve is mounted to the rail by means of an adapter, and the measured discharge of the valve is conveyed by means of a capillary tube through the

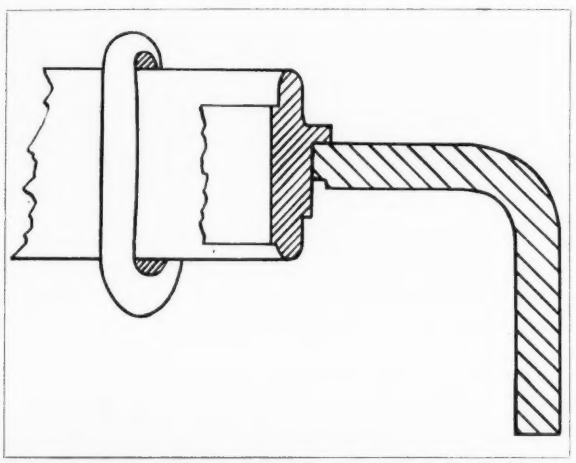

**Fig. 2. Section View of Ring Rail and Traveler.**

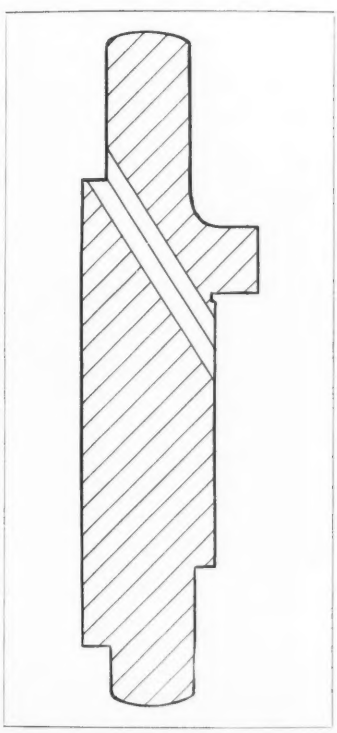

**Fig. 3. Section View of Drilled Ring.**

**Fig. 4. Electron Drill Drilling Hardened Rings.**

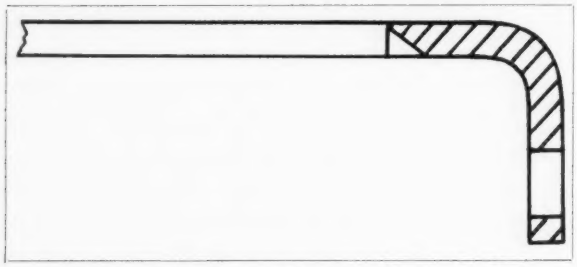

**Fig. 5. Rail Section Drilled and Slotted.**

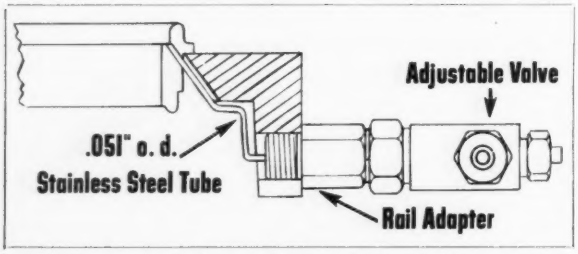


**Fig. 6. Measuring Valve and Tube as Mounted to any Ring or Rail.**

slot in the frame and the drilled hole in the ring to the desired point of application without interference with the thread or traveler.

The centralized lubrication measuring valves are then connected together and to a pump with ⅛ inch and ¼ inch tubing to form a closed centralized system.

The major difference in applying a centralized system to the rings of a spinning or twister frame and that of applying it to any other ordinary machine is governed by the requirement that extremely small quantities of lubricant, in the neighborhood of one-half of a thousandth (.0005) of a cubic inch is all that can safely be dispensed to each ring with each operation of the centralized system.

If appreciably more lubricant than this is dispensed at any one time, the excess lubricant would be struck by the rapidly moving traveler and splashed onto the yarn. Thus it becomes imperative that centralized measuring valves be selected for this application which are micro-adjustable, extremely accurate in measuring small quantities of lubricant, and are constant in their repetitive action.

Since the amount that may be dispensed at any one time is small and critical, the frequency of applications must be relatively close. Variations from once per minute to once every 3¼ minutes have been found to be successful. This approaches even, continuous lubrication, reducing frictional drag variation to a minimum.

The frequency of applications may be controlled by time clocks or synchronized with the movement of the rail section as it travels up and down to guide the thread onto the bobbin.

It was pointed out before that the possibility of eliminating downtown and lost production were justification enough to consider the application of centralized lubrication methods.

But, it is interesting to report some of the other advantages that have been noted after the application of centralized lubrication to spinning frame and twister frame rings.

First, consider the frame horsepower curve. Theoretically one would expect it to be a straight-line curve starting at a low point when the bobbins were empty and reaching a high point when the bobbins were loaded with a full weight of thread.

In practice, however, high points and low points occurred along this curve in direct relation to the lubrication of the ring and traveler.

As boundary-line lubrication occurred on the ring the horsepower curve would shoot up. When the ring was lubricated the curve would drop back to normal.

Variations in friction such as this will affect the quality of the yarn in spots. Centralized lubrication minimizes or eliminates this problem. Furthermore, it was noted that a reduction of from two to four horsepower per frame was attained from start to finish of filling a bobbin when the proper lubricant and the proper frequency of application were arrived at.

In some areas, one horsepower may be equivalent to as much as $35.00 per year savings. This figure, multiplied by the number of horsepower saved per machine times the number of machines in operation in one plant, can add up to a very appreciable sum.

Another important advantage is that by minimizing friction in the ring traveler area it is possible to increase the speed of the operation by as much as 20 to 40% on existing machines, and it is possible to mechanically modify existing machines to further increase the production potential in the same floor space area.

Even at the faster speeds with centralized lubrication the frames run as cool or cooler than before, and this can be important not only for comfort of personnel but it can mean additional savings where the machines are run in air-conditioned rooms.

Other advantages such as savings in lubricant, cleaner surroundings and appreciable reduction in fire hazard are also obtained.

# Testing Carbon for Seals and Bearings

by **R. R. Paxton**, Chief Engineer
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**A test method which has been of practical value in screening carbon-graphite materials for seals and bearings is described. Details of the relatively simple test stand are given. Typical experimental data are presented illustrating the use of this test stand to obtain performance data on one carbon base material running non-lubricated.**

## INTRODUCTION

Today's designer of seals and bearings must cope with increasing temperatures and pressures, higher rubbing speeds and generally more stringent performance requirements in almost every application. For this work he is offered a rapidly expanding list of new seal and bearing materials. Field experience and laboratory test data on these materials are seldom published with the result that seal and bearing design remains as much art as science.

The use of carbon in high performance seals and bearings has grown rapidly during the last decade. This growth has come notwithstanding the scarcity of published data on properties and performance of carbon-graphites. Publication of standard test methods together with typical data should be of interest to both seal and bearing designer and to the ultimate user of high performance pumps, gas turbines, and aircraft accessories which contain carbon components.

This paper presents a test method which has been used for many years to guide the development of carbon-graphites for seals and bearings. To illustrate the versatility of this test method, experimental test data are presented for one carbon-graphite running under a variety of operating conditions.

## EXPERIMENTAL

Fig. 1 shows a battery of test stands. Over half a million hours of testing have been accumulated on this one battery. The stands in the background are high temperature stands which operate dry at controlled ambient air temperatures up to 800 F. The central stands are unheated test stands and those in the foreground are stands that operate with aqueous solutions. These stands operate at speeds up to 4700 rpm with test pieces having a mean diameter up to 2 in. and at controlled loadings up to 500 pounds

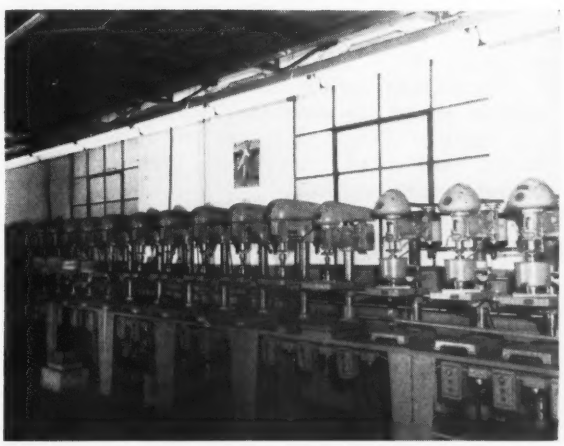

**Fig. 1. Battery of "Drill Press" Test Stands.**

per square inch. Fig. 2 is a closeup of an unheated test fixture.

Similar units equipped with explosion proof motors and switches are used for carbon wear tests in flammable liquids such as gasoline, JP-4, solvents, and lube oils.

The test stand is basically a 14 in. drill press with a special fixture between the table and the chuck. Fig. 3 is a drawing of the fixture used for high temperature tests. This is the most complex of the three types of test heads in service. The liquid test fixture is very similar to the heated one except that the heating enclosure is replaced by a tank with an inlet and outlet positioned to keep the liquid level above the carbon piece under test.

The top of Fig. 3 shows the drill press chuck connected to the driver. The driver in turn rotates the mating face (backface) by means of two pins. Also attached to the driver is a spinner to dissipate by convection heat drawn up the shaft. This copper spinner protects the chuck and the quill bearings from overheating. Directly below the mating face is the carbon test piece, which is restrained from rotating by slots that engage the restraining ring. The stationary test piece is pressed against the rotating mating face by a calibrated spring beneath a stainless steel washer. This washer distributes the spring load evenly over the back side of the test piece and reduces surface damage. The test piece, though restrained from rotating, is free to travel in the vertical axis.

A calibrated Ni-Cr-Fe alloy spring supplies the load to the test piece. Prior to the start of a test, the spring to be used is calibrated and the deflection required to produce the desired load is established. Test elements are then assembled and the required amount of compression is placed on the spring by lowering the chuck. At the end of the test the springs are measured and recalibrated to make sure they have not taken a set.

Each test stand is provided with two thermocouples. A hole is drilled into the test specimen approximately 3/32 inch below the rubbing surface and an iron-constantan couple is cemented in place. This couple shows actual carbon temperature. A second thermocouple is in the ambient air space adjacent to the seal. This couple controls operation of the heating mantle. The difference in temperature between these two couples is the temperature rise of the carbon due to friction.

The air tank, spring, washer, and carbon test piece are free to rotate on the thrust bearing shown in the lower part of Fig. 3. A torque pin on the bearing retainer permits one to take torque readings when the rotation lock is loosened.

Some of the stands in Fig. 1 have seen ten years of virtually continuous service. A preventative maintenance program which replaces worn parts quarterly has eliminated test interruptions because of breakdowns. First cost per stand is low and maintenance parts have been inexpensive because the unit is basically a standard mass-produced drill press.

The simplicity of the test head permits rapid changeover keeping downtime between tests to a minimum. Most of the mating faces can be reused many times by grinding and lapping after each test.

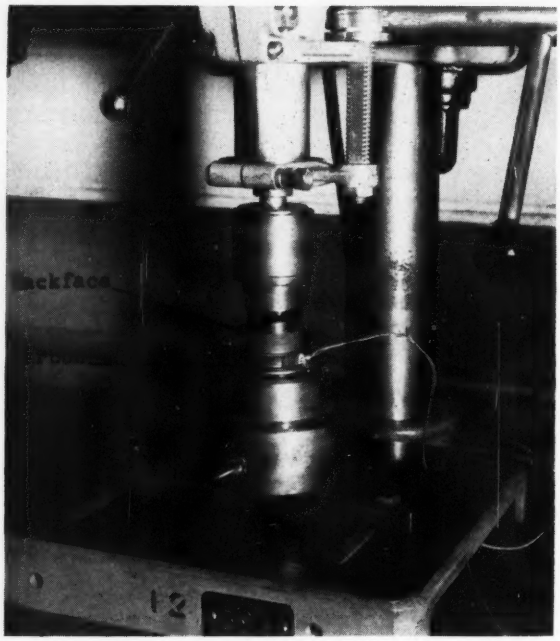

Fig. 2. Unheated Test Fixture.

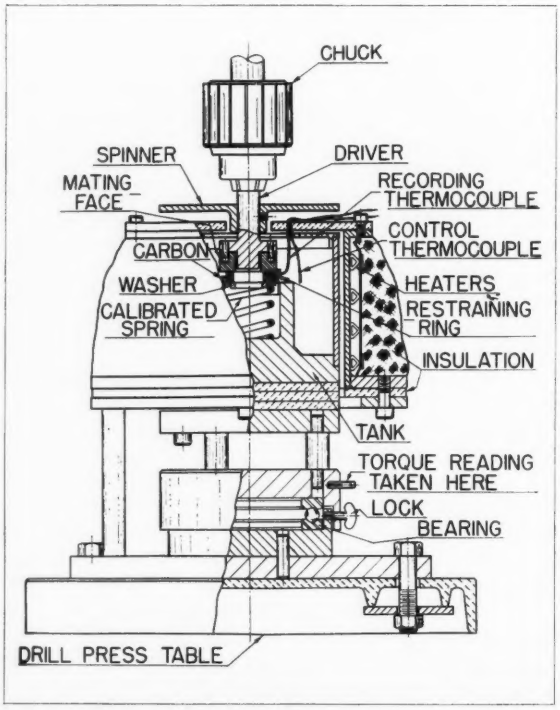


Fig. 3. Details of Heated Test Fixture.

A broad range of diameters and surface areas of the test specimen can be easily accommodated in this unit. The surface of the test specimen can be continuous to simulate a seal application or it can have radial slots to simulate a thrust bearing. All of the data which follow are for a continuous face simulating a seal application. Faces of this type do not allow for wear debris to escape from the rubbing surface and tend to show higher wear and higher friction than slotted faces.

## PROCEDURE USED FOR PREPARING METAL MATING FACES

The metal faces were first paralleled on a surface grinder starting with a 46-grit wheel and finishing with a 120-grit wheel using a surface speed of 6000 feet per minute. The rubbing face was then machine lapped.

After lapping, the mating faces were degreased and checked for flatness and smoothness. If not flat to within 3 light bands on an optical flat, they were relapped. The faces were then hand lapped in water against a 600-grit stone to provide a reproducible surface roughness. The surface roughness was read with a profilometer. In the case of chrome plated steel backfaces, the maximum allowable roughness was 6.5 rms micro inches. Cast iron backfaces are lapped in an identical manner, but because of their grain structures, surface roughness ranges from 15 to 150 rms micro inches. The cast iron used in these tests had a coarser grain structure than that ordinarily used for the manufacture of seal faces.

## PREPARATION OF CARBON FACES

Carbon faces were prepared in much the same way as the backfaces. After wet hand lapping, the carbons were hand lapped on dry 600-grit stones. The mating face of each carbon was checked for surface flatness in exactly the same manner as the backface. Hand lapping continued until the carbons had a surface flatness of 3 light bands or better.

Because of the porous nature of the carbon, measurement of surface roughness by a profilometer was omitted.

## SELECTING TEST DURATION

Over the past decade a number of tests have been made in which the run was interrupted, the wear measured, and the test resumed. Fig. 4 presents typical data for two specimens of the same grade run concurrently on an "interrupted" test which totalled 200 hours of running under a load of 20 psi. Wear of both specimens was essentially linear with time. Coefficient of friction and temperature rise on the other hand dropped during the early part of the test to reach a stable value after about 100 hours. On the basis of these and many similar sets of data, a test length of

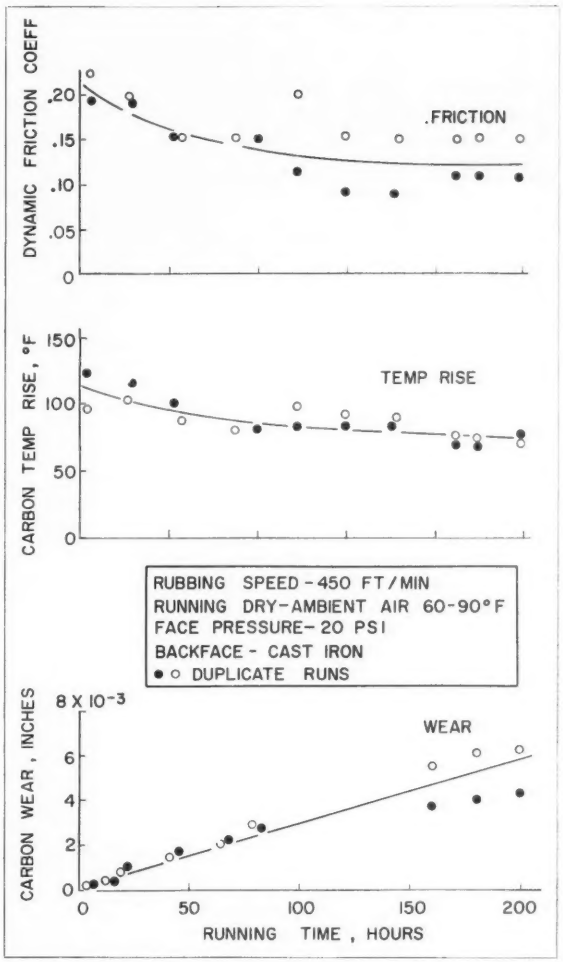


**Fig. 4. Effect of Test Length on Wear, Friction, and Temperature Rise.**

100 hours has been established as standard. All wear rates herein reported are based on total wear in this "standard" 100-hour test.

The relationships shown in Fig. 4 are typical. Occasionally, however, a carbon grade has been noted to wear rapidly the first 20 to 40 hours on test and then settle down to a much lower wear rate. The lifetime projected wear rate for such a carbon based on the "standard" 100-hour test will obviously be too high. Experience has shown that a 100-hour test permits a reasonable, though sometimes conservative, projection of lifetime average wear rate for carbon-graphite.

## REPRODUCIBILITY OF TEST RESULTS

To investigate the reproducibility of this test method, data from several hundred tests were assembled. The tests span a 10-year period and include all duplicates and replicates of this one base carbon, with and without impregnants, run dry (non-lubricated) in air at ambient temperatures from 75 to 500 F.

Among these tests were 88 replicates, mostly duplicate tests. These replicates were divided into four families. The first family included all replicates where the *average* wear of the pair (or replicate) was below 0.005 in. The other three families had progressively higher *average* wear. Then the standard deviation among the members in each of the four families was calculated using the method outlined in Youden (5). The shaded bars of Fig. 5 show that the standard deviation in each subgroup (or family) of replicates increased as the *average* wear of the family increased. In simple terms, the uncertainty was greatest where the wear was greatest. The number on each bar (Fig. 5) shows the number of replicates in that family.

Among the 88 replicates were 21 paired tests. In these instances the carbon-graphite test specimens were from the same production and impregnation lot. They were tested either simultaneously on adjacent test stands, or consecutively on a given test stand. The open bars of Fig. 6 show that the standard deviation of these matched pairs was about half the standard deviation of all replicates in the same wear family. Thus, it would appear that at least part of the variation among replicates was due to variation in carbon properties or test methods over the 10-year span under consideration.

## EFFECT OF RELATIVE HUMIDITY

The test apparatus which has been described makes no provision for controlling humidity of the atmosphere surrounding the specimen. It is well known that very low humidities can greatly accelerate the wear of carbon (3). Relative humidities ranging from 17% to 85% have been observed in the test room. Over this range, there has been no detectable effect upon the wear of either base-grade carbons or impregnated versions of the base grades. This is not too surprising, since even at 17% relative humidity the partial pressure of water vapor was 3 mm Hg, well above the 0-0.6 mm range at which excessive wear has been found by others (1).

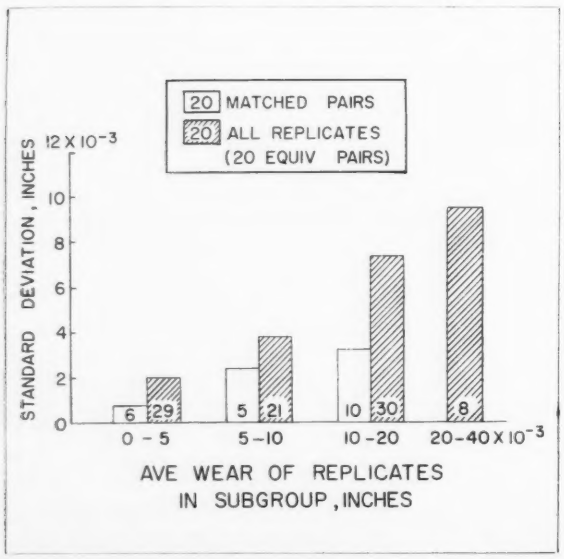


**Fig. 5. Reproducibility of Wear Values.**

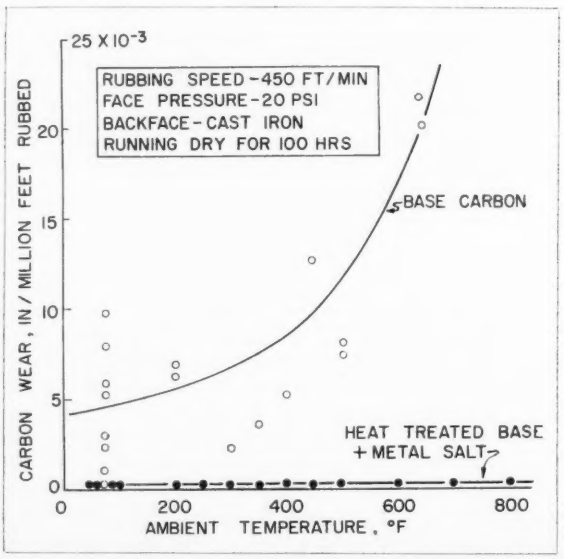


**Fig. 6. Effect of Ambient Temperature on the Wear Rate of Two Carbon-Graphites.**

## OPERATING FACTORS WHICH AFFECT WEAR RATES

Ambient air temperature, face pressure, rubbing speed, and mating face material are the principal factors which have been found to affect the wear rate of carbon-graphite materials running dry in air. The degree to which each of the factors affects performance, however, varies from base grade to base grade and depends on the type of impregnation and heat treatment the base grade has received. The purpose of the experimental data cited is primarily to illustrate the performance of the test stand. To avoid possible misunderstanding, all the data are for a single base grade. This base grade was a pitch-bonded synthetic graphite baked under carefully controlled conditions of temperature and furnace atmosphere. Physical properties of the base grade and the impregnated versions are tabulated in Table 1. The range in values shown for each property spans at least 90% of the values observed in the test specimens.

## OPERATION AT ELEVATED TEMPERATURES

One of the most useful features of the apparatus described is its ability to operate at controlled temperatures up to 800 F. Thus, one can explore the effect of this important factor over a relatively wide range.

Johnson, Swikert, and Bailey (2) have reported that carbon wear rates increase slowly with increasing carbon temperature up to about 400 to 600 F., then climb sharply with further temperature increases. Their rapid increase in wear rate began at 400 F. when the mating face was M-10 tool steel (Rockwell C-62). When the mating face was chrome-plated steel, the rapid climb in wear rate began at a carbon temperture of 600 F.

Fig. 6 shows the effect of ambient temperature on the wear rate of two carbons, the base grade and this same grade after heat treatment and impregnation with a proprietary chemical salt. Both materials were run against cast iron backfaces under identical conditions of speed and load; and each point represents a standard 100-hour test. Because of friction, actual carbon temperature was 100 to 150 F. above the ambient.

Performance of the straight carbon base grade was erratic, but in general it showed a sharp rise in wear when the ambient passed 400 F. Under these test conditions, the base grade carbon gave results similar to those reported by Johnson et al (2).

The lower curve on Fig. 6 shows the effect of heat treating and then impregnating this base carbon. Even at 800 F. ambient, wear was so small as to be scarcely measurable after 100 hours of running. Strength and hardness were likewise unaffected by 100 hours at 800 F.

The two curves of Fig. 6 show the sizable effect that heat treatments and additives may have upon the performance of a given carbon-graphite.

## EFFECT OF RUBBING SPEED

The second major factor influencing carbon wear which this test stand lets one explore is rubbing speed. Fig. 7 shows how rubbing speed affected wear rates, temperature rise, and coefficient of friction of two carbon grades. The test specimens of each grade were selected from a single lot to insure uniformity, and the tests were run simultaneously in ambient air at 75 F., 24-36% relative humidity, and with a face pressure of 20 psi against cast iron mating faces.

The wear on the base carbon was essentially proportional to the distance rubbed up to a rubbing velocity of 500 feet per minute. Further increases in rubbing speed accelerated the wear rate of the base grade. As before, heat treating and impregnating the base grade with a proprietary chemical salt reduced the wear to barely measurable levels.

Temperature rise of both carbons increased with increasing rubbing speed up to 600 feet per minute. Between 600 and 1000 feet per minute rubbing speeds, both carbons ran roughly 200 F. above the 75 F. ambient temperature.

Dynamic coefficient of friction generally fell as the rubbing speed increased. The exception to this was the base grade carbon at rubbing speeds below 300 feet per minute where friction was erratic, and on the average well below the friction of the heat treated, impregnated version. It is interesting to note that these two carbon materials with such widely differing wear rates have nearly identical coefficients of friction. This is not new. Wisander, Maley, and Johnson (4) have reported carbon wear rates in liquid nitrogen

TABLE 1
PHYSICAL PROPERTIES

| *Carbon Graphite Test Specimens* | *Scleroscope Hardness*[a] | *Apparent Density, gm/cc* | *Transverse Strength, psi* |
|---|---|---|---|
| Base Grade | 40–50 | 1.56–1.63 | 4,400–6,000 |
| Synthetic Resin[b] | 62–75 | 1.65–1.75 | 8,100–11,000 |
| Babbitt Metal[b] | 50–65 | 2.30–2.70 | 8,000–9,300 |
| Silver Metal[b] | 50–60 | 2.60–3.10 | 8,700–9,800 |
| Chemical Salt[b] | 40–55 | 1.65–1.72 | 4,500–6,200 |
| Heat Treat+Salt | 38–50 | 1.60–1.70 | 5,400–6,600 |

[a]Shore C Scale
[b]Impregnants

which varied by a factor of 100 to 1 with no difference in friction.

## EFFECT OF FACE PRESSURE

Through the use of different springs together with different contact areas, this apparatus permits exploration of a wide range of face pressures. Fig. 8 shows the influence of increasing face pressure on wear and on temperature rise for two carbon grades. In these tests all the specimens had 0.42 square inch rubbing areas, increased pressure being obtained by using different springs and spring deflections in the test head. As in the preceding case, the test specimens were selected from a single lot and run simultaneously. The environment was air at 75 F. and a relative humidity of 26-29%. All specimens were run against a cast iron mating face at a speed of 450 feet per minute.

In both cases there was a loading above which wear started to climb rapidly. For the base carbon this loading was about 12 psi. Addition of the proprietary salt earlier referred to increased the permissible loading to 35-40 psi. The additive also reduced carbon temperature rise at all loadings.

## MATING FACE MATERIALS

A fourth and highly significant variable in seal and bearing design, which can be explored on this test stand, is mating face material. Johnson, Swikert, and Bailey (2) concluded their recent study of seal materials with the feeling that selection of the mating face material was at least as important as selection of carbon grade. Experience with this test stand confirms that mating face material often has an important effect upon carbon wear rates.

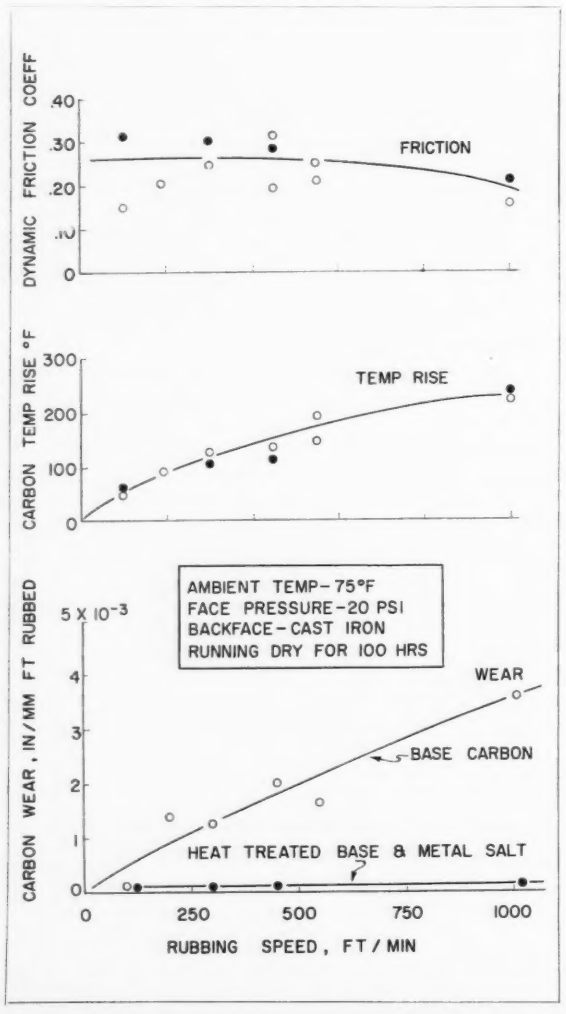


Fig. 7. Effect of Rubbing Speed on Wear Rates, Coefficient of Friction, and Temperature Rise of Two Carbon-Graphites.

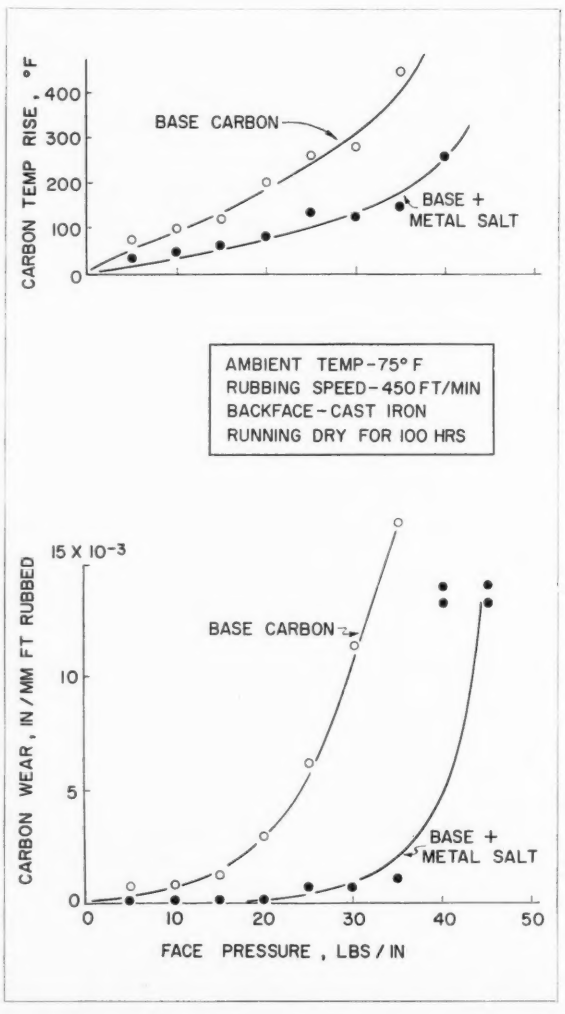


Fig. 8. Effect of Face Pressure on Wear Rates and Temperature Rise of Two Carbon-Graphites.

Fig. 9 shows typical average wear rates for four versions of the base grade. In most instances the rates shown are averages of several 100-hour tests under the conditions shown. In all cases the loads were 20 psi and the rubbing speed was 450 feet per minute. All the mating faces were lapped flat to 3 light bands and to the standard smoothness. The front or unshaded columns show wear rates in 75 F. ambient air. The rear columns show wear rates for "high temperature" operation, normally 500 F. ambient air. Mating face material is shown at the top of each column.

The heat treated, salt impregnated version of the base grade gave lowest wear on both high-temperature and low-temperature dry running tests. Cast iron or chrome-plated mild steel mating faces gave equally good results. If the heat treatment was omitted, however, only the cast iron mating face gave low wear rates. The variation in wear rates caused by mating face materials is not so striking in the case of babbitt and silver impregnated base grades.

Similar data have been obtained on these grades for other test conditions, and on many other grades. In some instances mating face material had a decided influence on carbon performance; in others there was no discernable effect. At present the only generalization that can be made about mating faces for dry running carbon is that they must be smooth and hard. Surfaces rougher than 15 rms micro inches often lead to higher carbon wear. Soft materials such as mild steel, brass, or aluminum are generally unsatisfactory for dry running where long life is desired. Apart from these two generalities, there is no substitute for test data or field experience in selecting the optimum carbon-mating face combination for a given application.

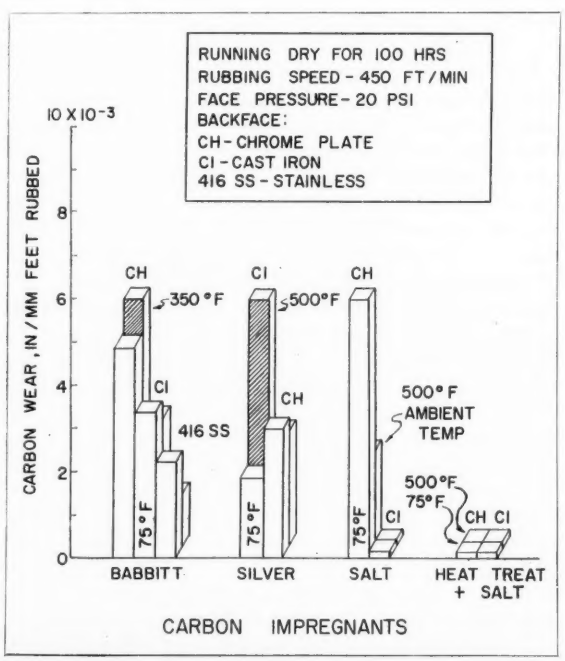


**Fig. 9. Effect of Mating Face Material and Temperature on Wear Rates of Four Carbon-Graphites.**

Principal factors that enter into these selections are nature of the surrounding fluid, temperature, face pressure, and rubbing speed. In most cases delivery time and cost must also be considered.

## SUMMARY AND CONCLUSIONS

This inexpensive yet versatile test stand has been successfully used to develop seal and bearing materials. Data have been presented to show the reproducibility of results that may be expected. The use of this unit to explore the effect of temperature, face pressure, rubbing speed, and mating face material under dry running conditions is illustrated. This test stand can also be used to explore these same variables in the presence of other fluids such as water, solvents, and oils.

In addition to illustrating the use of the test stand, the data show that temperature, face pressure, rubbing speed, and on occasion mating face material have a sizable effect on carbon wear rates. Perhaps even more important, the data show that, under a given set of operating conditions, two variants of the same base grade have markedly different wear rates. Satisfactory performance and life from a carbon-graphite seal or bearing depends upon selecting the right carbon-graphite and mating face for the environment. It also depends upon having a design which does not overload the interface, and upon careful manufacture to produce smooth, well aligned faces.

The use of carbon-graphite in seals and bearings is growing rapidly. Applications impossible five years ago are routine today. Non-lubricated bearings and seals of carbon-graphite run several hundred hours in 1000 F air. Rubbing speeds of 10,000 feet per minute are no longer unusual. Increased knowledge makes it possible to custom design stronger, more uniform carbon-graphites for new and difficult applications. Designers who are familiar with the unique properties of carbon-graphites find them useful to solve difficult friction problems in devices ranging from watt hour meters to aircraft gas turbines.

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# Centrifugal Purification of Lubricating Oil

**The utility of a lubricant is reduced by the accumulation of contaminants; it does not wear out. Most contaminants exhibit a phase and density difference and lend themselves to centrifugal removal.**

**Centrifugal oil purifiers are of two types**

1. **The tubular type rotor.**
2. **The disc type rotor, that can be modified to permit continuous discharge of sedimented contaminants.**

**A new system permits full use of the disc stack of the latter for purification of the oil phase.**

**There are three types of purification systems; Batch, Continuous Full Flow, and Continuous By-Pass. Each may be supplemented by gravity settling, straining and filtration.**

**To keep any system in balance the contaminants must be removed at the rate they accumulate. For optimum performance the same critical attention must be given to the design of the purification system as was given to the initial selection of the lubricant.**

**by Charles M. Ambler,**

**Director of Chemical Engineering,**
**The Sharples Corporation, Philadelphia, Pa.**

The purpose of a lubricant is to facilitate the motion of two surfaces with respect to each other and to transport away from these surfaces the frictional heat generated by this motion. The basic principle is that a lubricant does not wear out; it becomes contaminated, even under normal service conditions.

It is the accumulation of contaminants that reduces or even destroys the utility of the lubricant for further service. Their removal becomes an economic necessity to permit the satisfactory continued use of the lubricant and to minimize its replacement cost.

Unless the same critical attention is given to the purification of the lubricant, as was given to its initial selection, optimum performance during its use will not be obtained.

The type and degree of contamination of a lubricant is a function of its service conditions; e.g., the impurities in used grinding coolant will be largely particles of metal from the work and abrasive and binder from the wheel. Moisture may come from atmospheric "breathing" and condensation, and from leakage of steam or cooling water. Metal and oxide particles and foundry sand loosened from the cast parts will be found in used turbine oil. Fine metallic particles created by abrasion and metal forming operations will be found in gear and internal combustion engine lubricants.

Another source of contamination is the atmosphere to which the lubricant is exposed. Moisture has already been mentioned. In addition, the lubricant in a cement mill will be contaminated with cement and rock dust. Iron oxide from the blast furnace and scaling operations will be found in the steel mill lubricant.

A third type of contamination results from the breakdown of the lubricant itself, such as the carbon formed in an internal combustion engine or sludge created by less severe partial oxidation of the oil. The formation of such sludge is usually catalyzed by the presence of fine metallic particles, making their removal doubly important.

All of these contaminants appear as discrete particles or phases, usually of significantly different density from that of the lubricant itself.

The theory of centrifugal separation and purification has been discussed elsewhere at considerable length (1, 2, 3), but it may be briefly stated that the commercial sedimentation type of centrifuge, such as the centrifugal oil purifier, is a mechanical device for accelerating the separation of two or more phases when a difference in density exists between them.

Centrifugal force as applied in commercial sedimentation centrifuges differs only from the force of gravity in that

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It may be several orders of magnitude greater than the force of gravity, and

It is applied in all directions from a center of rotation.

Centrifugal force has parameters similar to those of gravitational separation, and the anticipated performance of the various types and sizes of centrifuges may be compared on the basis of the equivalent area of a gravity settling tank capable of delivering the same amount of useful separative work.

The calculated equivalent area of a given centrifuge has been considered by the author and others as its Sigma value and leads to the concept that the throughput rate of the fluid being purified, Q, divided by the Sigma value of the centrifuge has a fixed relation to the extent that the fluid will be purified. The analogy is that if a settling tank having 100 square feet of area can do a required job of clarification at a throughput rate of 100 gallons per hour, then a geometrically similar tank of 200 square feet area can do the same job at 200 gallons per hour.

The factors involved in the Sigma value of the centrifuge are the integrated centrifugal force over the radius of the centrifuge rotor, the average distance a particle of the dispersed phase must be moved to separate it from the system, and the length of time the continuous phase containing the dispersed particles is subjected to the action of centrifugal force.

The type of impurities accumulated by used lubricants are those which, in general, respond to gravitational or centrifugal separation, since usually the required difference in phase and density exists.

Centrifugal oil purifiers are of two general types. Fig. 1 illustrates the tubular type, which is characterized by a rotor revolving on a vertical axis that is relatively long with respect to its diameter. It depends on its high rotative speed and very high centrifugal force, which is proportional to the square of the rotative speed, up to 16,500 times the force of gravity, to perform the required purification. Among its other advantages are simplicity of construction and ease of cleaning. Fig. 2 illustrates schematically the disc type of centrifuge, also rotating on a vertical axis, which operates at lower rotational speed because of stress considerations due to its larger diameter and gains its efficiency by minimizing the distance a particle must move radially between adjacent discs to be separated from the fluid phase.

In both types the liquid flow is continuous, oil being discharged from near the center, and the heavier water phase from nearer the outside of the rotor, while solid impurities that have been separated out are accumulated within the rotor for manual removal at required intervals.

The disc type of centrifugal separator lends itself much more readily to modification to permit the continuous discharge of the separated solids, thereby reducing the amount of direct operating labor, as will be discussed later.

It having been determined that the undesirable contaminants in the used lubricating oil are of a type that can be removed by centrifuging, there are several systems available:

Batch purification

Continuous full flow purification

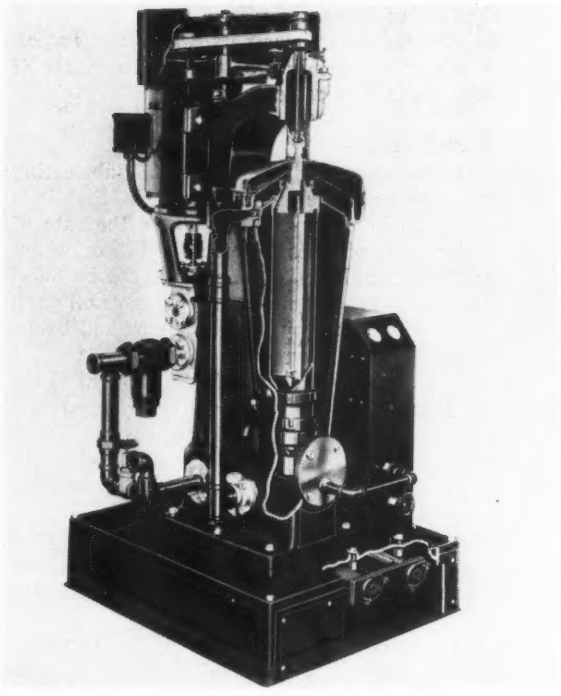

**Fig. 1. Tubular bowl centrifuge with self contained pumps and heater.**

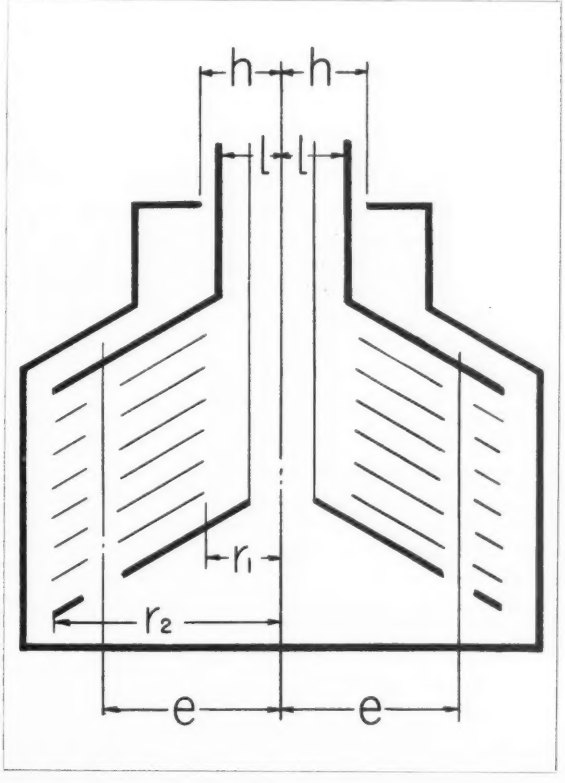


**Fig. 2. Disc bowl centrifuge—schematic diagram.**

Continuous by-pass purification

Each of these has its own particular set of values, with the selection depending on the requirements of the system being lubricated.

**1. Batch Purification—**

For the case of a number of individual lubricating oil sumps, such as a line of machine tools, that it is not desirable to interconnect, and where the rate of accumulation of impurities is relatively low or where a substantial accumulation of impurities can be tolerated before purification is necessary, portable oil purifier complete with auxiliary heater, pumps and transfer tank would offer a convenient solution.

At suitable intervals the purifier is brought to the individual sump whose contents are centrifuged into the transfer tank to permit the sump to be washed clean while empty. The cleaned oil would be returned to the sump with such added makeup as is necessary and the purifier moved to the next location.

In some cases it may be preferable to transport the oil to the centrifuge which has been installed at a convenient central location, but the basic technique is the same.

Such a system is illustrated in Fig. 3, where provision is also made at the central location for additional purification by water washing and supplementary gravity settling ahead of the centrifuge.

**2. Continuous full flow purification—**

This is employed when it is considered desirable to remove all the contaminants in every pass before the lubricant is reused. A typical example is block test oil purification where the engine or other mechanical device on the test stand is only to be operated on purified oil.

Two schemes for accomplishing this are illustrated in Figs. 4 and 5.

In these cases, centrifugal capacity in excess of the maximum circulating load is required so that the contaminated oil from the dirty oil tank is passed through the purifier and into a clean oil tank from which the return to the test stand is drawn either by gravity or by pump. The clean oil tank is maintained at constant level by adjustment of the flow rate to the purifiers and the excess, if any, is allowed to overflow back to the dirty oil tank for recirculation through the centrifuge battery. In this manner the "clean oil tank" is maintained at proper level with a continuing supply of purified oil.

**3. Continuous by-pass purification—**

This type of purification installation is used when a level of impurities can be tolerated in the system provided all impurities in excess of this tolerable level are removed as fast as they are introduced. Typical examples are a turbine oil or steel mill lubricating oil sump.

Fig. 6 illustrates such a system applied to the purification of rolling mill oil in which the purification obtained by centrifuging is assisted by gravity settling in the 8000 gallon tanks and by a full flow strainer in the return line to remove any coarse solids from the circulating loop. It should be noted that in this system the supply to the centrifuge is taken from the bottom

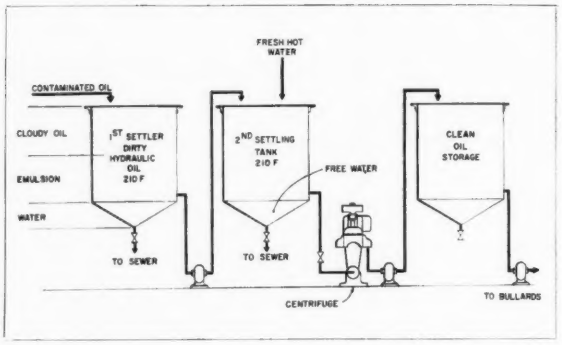


**Fig. 3. Batch system for purification of hydraulic oil containing up to 70% water soluble coolant. Purified oil in Clean Oil Storage Tank is bright and clear, equivalent to new oil.**

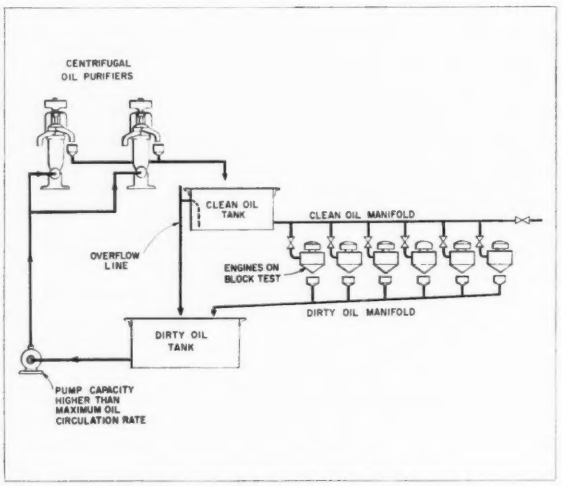


**Fig. 4. Full flow oil purification set up for block test oil.**

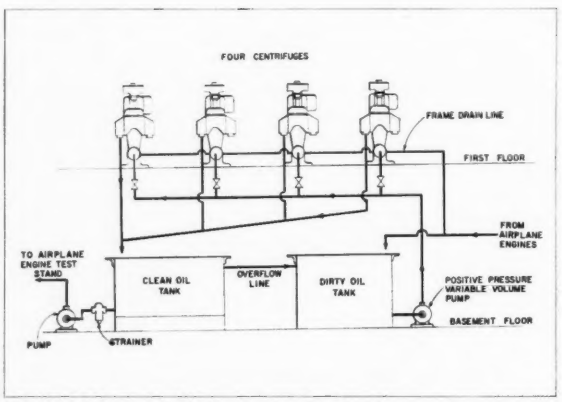


**Fig. 5. Block test oil purification set up in which circulation is continuous and oil is centrifugally purified after each pass through the engines. Only cleaned oil is returned to the test stands.**

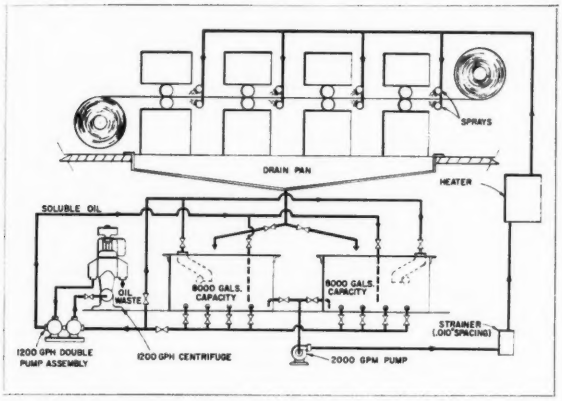


**Fig. 6. Purification of rolling mill oil with the centrifuge on a continuous by-pass system with purification supplemented by gravity settling and straining of the full flow stream.**

of the surge tanks, the point at which the concentration of impurities is highest.

In many cases it will be found desirable to supplement centrifugal purification with gravity settling, either to reduce the solids loading on the centrifuge or in the case of continuous by-pass purification to get some benefit of gravity settling in the main circulating loop, while at the same time concentrating the impurities in the underflow stream to the centrifuge. In many cases it will also be found desirable to include full flow straining to remove coarse insoluble solids and obtain the same benefits.

One of the factors exerting a strong influence on the degree of purification of an oil that can be effected by centrifuging is the viscosity of the oil. Since most lubricants have a fairly steep viscosity temperature gradient, the degree of purification can be considerably improved by increasing the temperature of the oil prior to centrifuging. Furthermore, since the density of the oil tends to decrease faster with a rise in temperature than does the density of either water or insoluble impurities, a further gain is realized since the separative effect of the centrifuge is influenced by the difference between the density of the oil and the density of the impurities that are to be removed from it.

As was previously noted, the disc type centrifuge rotor, being short with respect to its diameter, lends itself to modification to permit continuous discharge of the sedimented solids through peripheral discharge ports along with a portion of the heavy phase. Fig. 7 illustrates the construction of a conventional nozzle type separator bowl with the inside of the bowl shell sloped to direct the solids that have been sedimented out in the disc stack toward the nozzles. In this rotor the hydrostatic balance that keeps the oil/water interface at its optimum position in the feed zone is maintained in a conventional manner with a ring dam of properly selected size at the top of the rotor. The amount of liquid discharging through the nozzles is a fixed function of their size and number, and provision is made at the bottom of the rotor to introduce a supplementary amount of water to satisfy the demand of the nozzles in the event that the required quantity is not present as water contamination in the feed stream. This supplementary water is introduced outside the disc stack so that the disc stack is only used for the purification of the feed stream and is not loaded with the recycle water.

In such a rotor, practically all of the useful separative work is done in the disc stack where the travel path of the particles of impurities is held to a minimum. It will be noted in the illustration that a large proportion of the disc stack is outside the feed holes and is only useful for doing work on the separated water phase which ordinarily gives up its oil content quite freely. It must be further realized that the separative work that is done in such a disc stack is proportional not either directly to the radius nor to the area of the disc but actually to the cube of the radius, so that any small increment by which the radius at the interface can be increased greatly increases the ability of the centrifuge to purify the important light oil phase.

Furthermore, when a contaminated oil containing water is subjected to either gravity or centrifugal force, four layers are formed. The inner or top layer is the light phase oil, followed by an interfacial layer of oil/water emulsion, a layer of separated water and an outer layer or sedimented solids. It is desirable to apply the maximum of force to this interfacial emulsion layer to resolve it as completely as possible, otherwise it either must discharge with the oil phase subtracting from the oil phase purity, or with the waste water phase creating a loss of valuable oil. Since centrifugal

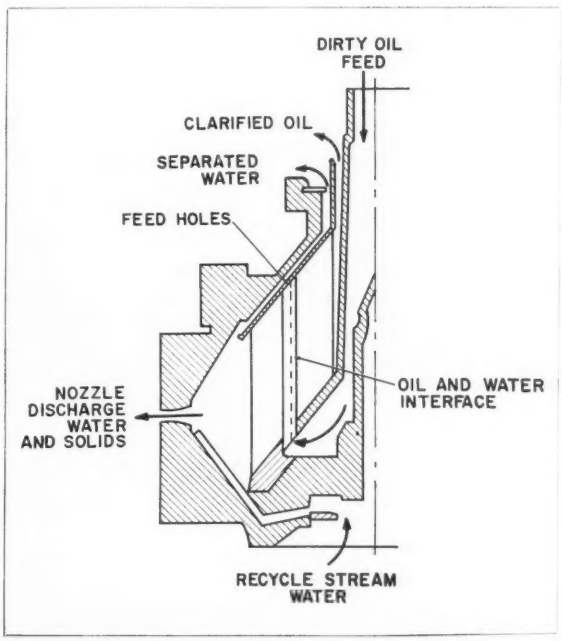


**Fig. 7. Conventional nozzle-type disc separator bowl with feed distribution holes in the disc stack.**

force varies directly with the radius, another reason is provided for moving the interfacial layer as far from the center of rotation as possible. The ultimate on both counts is attained by moving the interfacial layer outside the disc stack. For consistent performance, the location of this interface requires very close control, and the above objectives can only be attained by limiting the radial distance in which the interfacial layer can exist. It must be outside the OD of the disc stack but sufficiently inside the line of the nozzles to avoid loss of oil through them. The concept is that of a two liquid phase system with contact only at the interface through which the solid contaminants are transferred.

In operation, the bottom recycle dam is selected to properly position the interface on the basis of the relative densities of the oil and aqueous phases at the selected operating temperature according to the formula $E = \frac{e^2 - h^2}{e^2 - l^2}$, in which E is the ratio of the density of the heavy aqueous phase to that of the light oil phase at the operating temperature, e is the desired radius of the interface, h is the radius of the recycle ring dam, and l is the radius of the light oil phase discharge.

The resultant positions of the several phases are illustrated in Fig. 8.

Sufficient water is introduced through the recycle to satisfy the fixed requirements of the nozzles, plus a slight excess as a safety factor. The dirty oil feed is now introduced. Any water present in it is separated causing the total instantaneous water flow in the rotor to exceed the capacity of the nozzles. This in turn causes the interface line to attempt to move toward the center but since the system is in hydrostatic balance, this results in the excess of water overflowing the recycle dam, or, in effect, causes the bowl to reject the amount of the recycle stream that is not required to satisfy the nozzles. Even if one or more nozzles is plugged by extraneous solids, the system within the rotor remains in equilibrium. The equilibrium can only be disturbed by a change in the relative densities of the two phases. In most cases the oil phase of the feed is a uniform material and its density can be fixed by thermostatic control of the feed temperature. It will be noted from the illustration that there is limited contact beween the feed stream and the recycle water stream, and therefore considerable density control of the latter by temperature regulation is possible, and the interface line position can be regulated by heating or cooling the recycle water as required. When such a centrifugal purification system is applied to fuel oil, the degree of regulation is adequate to cover 5 API degrees variation in

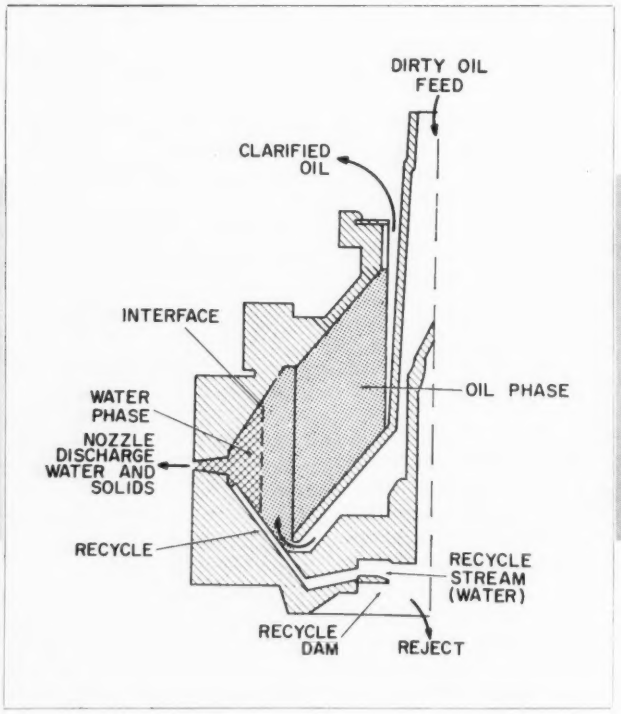


**Fig. 8. A new principle applied to nozzle type disc bowl illustrating full utilization of disc stack for light phase purification and application of maximum centrifugal force to resolution of interfacial emulsion.**

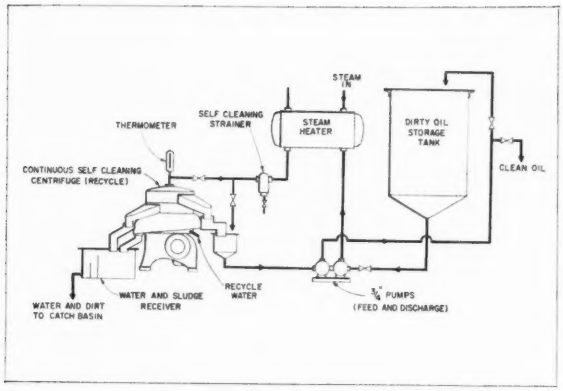


**Fig. 9. System for purification of waste oil for fuel utilizing the entire disc stack for purification of the oil phase.**

the feed stock. Fig. 9 illustrates the installation of such a system as applied to the purification of waste oil for fuel. Conventionally, the recycle water will be taken from the full side of the "water and sludge receiver", although in this particular installation fresh water at controlled temperature has been used.

There are many factors to consider in setting up a proper lubricating oil purification system, centrifugal or otherwise. Typically, the purification system must be of adequate size and capacity to remove the contaminants at the same rate that they are being introduced into the lubricant. This may be in terms of pounds per week on a machine tool sump where intermittent batch purification fits the requirements, or grams per second on the run-in stand of a precision assembly where full flow purification of the lubricant is required. It seems obvious, but is frequently overlooked, that unless this rule is followed, impurities will accumulate in the lubrication system.

The degree of purification per pass through the purifier system must be adequate to fit the lubricant for continued service. Unless this is accomplished, the residual contamination precludes its further use.

In some lubrication systems inexpensive filtration or gravity settling provide an adequate solution. In many, these must be supplemented by centrifugal purification.

A typical example is the rolling mill oil system illustrated in Fig. 6.

In many steel mill lubricating oil systems, gravity settling and full flow filtration are combined to do a satisfactory job under normal operating conditions. These do an excellent job and present no problem until the first cooling water gland springs a leak. Under the severe conditions encountered, stable emulsions are quickly formed that can only be resolved by centrifuging. The same is true of marine diesel lubricating oil and of turbine oil systems.

Centrifugal purification of lubricating oil plays a very important role in modern diesel lubrication practice. Straight run mineral oils are less than satisfactory when the engines are operated continuously at rated load. This heavy continuous duty can only be satisfactorily handled with highly detergent oils. However, the filters that serve so well to keep the straight run oils clean cannot be as satisfactorily used on the detergent oils, and without purification frequent oil changes are necessary. The detergent content of the oil that does such an excellent job of keeping carbon deposits off the engine parts, does it by dispersing and keeping in suspension the carbon formed by the partial oxidation of the base oil. These finely divided carbon particles almost immediately plug the pores of the conventional filter before it can accumulate its normal loading of the more abrasive solids of larger particle size.

This is an ideal system for centrifugal purification which will remove all of the abrasive particles down to a micron or so in size. Since this purification is by straight forward centrifugal subsidence with no porous membranes or filter surfaces to clog up, the small harmless particles of soft carbon which clog the filter do not interfere with the separation of the abrasive particles.

The centrifuge is playing an increasingly important role in oil purification and there is an increasing trend toward fully automatic purification systems which is being anticipated by centrifuge manufacturers. For optimum performance the same critical attention must be given to the design of the oil purification system as was given to the selection of the lubricant with full congnizance of the required service and operating conditions.

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# NEW DEVELOPMENTS IN

# *Metal Working*

**Machining and working of new types of high melting, high strength and reactive metals has necessitated development of suitable methods of forming and in many cases, a review of lubrication procedures.**

**Strength versus corrosion resistance in new alloys, and sensitivity of these metals to gas absorption at high working temperatures have in many cases necessitated working below the recrystallizaiton temperature, increasing the lubrication problem.**

**Lubricant properties at the metal interface, and thickness of lubricant film may be more important than low friction. Cooling requirements may exceed necessity for lubrication, dependent upon surface chemistry.**

**Many common points are found in older and newer lubricants and methods of use, requiring appropriate interpretation of signicance of surface-active constituents, particularly in boundary lubricants. Overall effectiveness of the fluid depends on net energies of attraction at interfaces where surface-activity is requisite, as in extrusion and drawing.**

**In other methods of working, as in high-energy forming, electrical discharge and chemical machining fluids are used as energy-transfer media, dielectrics, electrolytes, hydraulic and carrier vehicles.**

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## INTRODUCTION

Many of today's metalworking problems relate to production-forming of high melting point, refractory, and even reactive metals, and the machining of these and other "super-alloys".

More conventional nickel-chrome ferrous alloys and several categories of stainless steels suitable for high-temperature services, have given way to a new species of super-alloys having higher heat resistance, i.e., from 1200F to within 100F of their melting points. (1)

The nickel-cobalt base alloys, suitable to service temperatures of ca 1700F, are already obsolete for some applications wherein required service temperatures may be in the range of 1800-3000F.

Table 1 shows a summary of super-alloys listed in a rough order of their strengths at increasing service temperatures:

TABLE 1
TEMPERATURE SERVICE OF SUPER-ALLOYS

| SERVICE TEMPERATURE RANGE | TYPE OF ALLOY |
|---|---|
| Up to 1300F | Iron Base Ni–Cr. |
| 1300–1400 | Ni–Mo. |
| 1400–1500 | Ni–Mo–Cr. |
| 1500–1600 | Ni–Mo–Fe–Cr. |
| 1600–2000 | Cr–Co–Ni–W. |

Super alloys must have heat resistance and strength, and must also retain certain corrosion resistant properties.

The Ni–Mo–Cr and Ni–Mo–Cr–Fe alloys are representative of those designed for corrosion resistance, and used as well in high-temperature applications.

The refractory metals, tantalum, molybdenum, columbium, and tungsten have extremely high strengths in the 2000-3000F. temperature range, i.e., ca 10,000 psi tensile at 2200F (2).

Presented at the 14th ASLE Annual Meeting, Buffalo, N.Y., April 1959

Table 2 and Fig. 1 show properties for these metals. Their principal limitations are that they oxidize readily and embrittle on contact with gases at high temperatures.

TABLE 2

MELTING POINTS OF REFRACTORY METALS

| | APPROXIMATE MELTING POINT, (°F) |
|---|---|
| *Ordinary Metals* | |
| Aluminum | 1200 |
| Copper | 2000 |
| Nickel | 2600 |
| Iron | 2800 |
| Vanadium | 3100 |
| Titanium | 3100 |
| Zirconium | 3100 |
| Chromium | 3400 |
| *Refractory Metals* | |
| Columbium | 4500 |
| Molybdenum | 4700 |
| Tantalum | 5400 |
| Tungsten | 6100 |

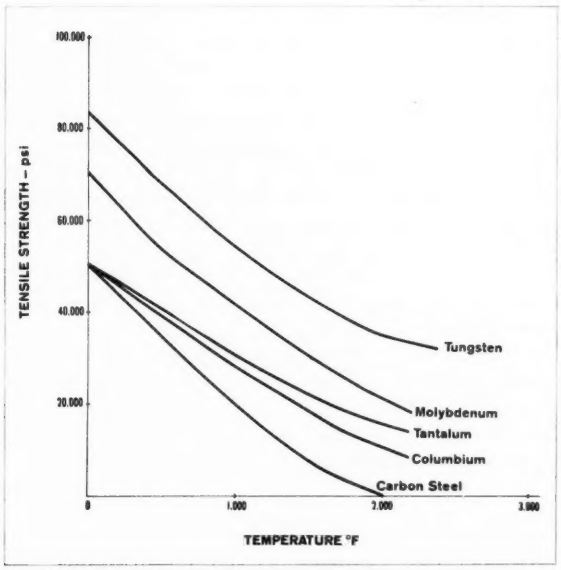


**Fig. 1. Refractory Metals, Tensile Strength vs. Temperature.**

Consequently, they require protection against disintegrating effects of oxygen, hydrogen and nitrogen at high temperature, both in manufacture and service. A promising technique is to "clad" the high-temperature metals with oxidation-resistant alloys such as Nickel-chrome combinations. Thin layers of buffer metals between the two help to offset otherwise poor alloying properties. Other methods used are plating, metal diffusion, and ceramic coating.

Titanium alloys are no strangers to the metal-fabricating shop, and many problems relating to material supply, properties control, and modes of fabrication are now fairly well known.

The high strength-to-weight ratio of titanium makes it attractive for aircraft and structural use, and its excellent resistance to corrosion qualifies it for many chemical industry applications.

New high-strength, low-alloy steels and certain superstrength steel are coming into broader use, based both on economy and structural performance where a high strength to weight ratio is indicated. Some of these alloys test at ca 300,000 psi tensile strength. These high strengths are ordinarily associated with relatively low ductility, hence seriously affecting fabrication and forming problems in the shop.

The difficulties encountered in fabrication of nuclear metals like zirconium, beryllium, thorium, hafnium, uranium, and yttrium are exotic, but no less real nor important than those encountered with ordinary metals. Although these nuclear materials are widely different, one from another, in many properties, they have two characteristics in common. They are all strongly reactive, and tend to weld and stick to tool and forming surfaces when worked (3). These metals exceed titanium in reactivity at the higher temperatures often encountered in working.

It is necessary to prevent any direct contact between such metals and tools used in working; otherwise the forming operation fails. By alloying, as with tungsten and molybdenum, it is possible to work zirconium at somewhat lower temperatures to relatively high strengths (4). Confronted with work-materials of the character described here, fabricating plants responsible for some of the new "manufacturing miracles" have of necessity engineered new processes and methods for working them.

These processes frequently involve methods of cold-forming rather than hot working, in order to permit fabrication of surface-reactive materials without getting into problems of metal-gas absorption and reactions inherent in hot-working.

Studies in the field of lubrication indicate that for processes of continuous deformation (as in rolling or drawing) the properties of the lubricant at the interface and the thickness of the lubricant film established, considerably influence the finish of worked surface obtained (5) and may be more important than friction reduction.

An appraisal of lubricants and forming compound required indicates many points of common character with more conventional metalworking fluids and solids. Certain basic fundamentals are found unchanged, although new interpretations of the significance of surface-active constituents in boundary lubricants are being constantly developed, and engineered into new methods of requisite lubrication in metalworking.

## FUNDAMENTALS OF FLUID REQUIREMENTS

There are two functional requirements for all metal-working fluids, namely cooling and lubrication. The importance of each for a specific fluid is determined by the operation in which the fluid is used. Fluids may range from water having maximum cooling to compounded oil having good lubrication. Many fluids com-

bine cooling and lubrication, as in an emulsion of oil and water, or as a mineral oil of relatively low viscosity.

In the use of fluids, the application of principles of surface chemistry is of importance. The effectiveness of a metalworking fluid may be considered, briefly, to be the net result of the energies of attraction at the various interfaces occurring in a system.

The lubricating qualities of most oils are determined by their hydrodynamic and boundary film properties. The former is principally a function of viscosity and the cohesive attraction between oil molecules as evidenced by the surface tensions of oils. These are not generally subject to wide variation, and desirable characteristics are often referred to by such evasive terms as good oiliness, wetability, lubricity, or surface activity. Fundamentally, it is believed that for the best lubrication, an oil film should have the highest energy of attraction or adhesion for a metal surface. This attraction in the case of a straight mineral oil, is greatly increased by addition to the oil of certain polar-type additives which have a strong affinity for both oil and metal. Some elements, such as sulfur and chlorine in certain oil soluble compounds, may have a much greater affinity for metal than for oil. They may be attracted from the oil and chemisorbed or chemically combined with the metal as a new compound to form an extreme pressure film which prevents metal to metal seizure.

Emulsions of oil and water are used for metalworking where better cooling is required than straight mineral oil will provide, or for some other service reason, such as to obtain better economics or a reduced fire hazard. The surface chemistry of such systems is complicated by a second interface between the oil and water coolant phases in addition to the lubricating fluid-metal interface.

A typical commercial soluble oil usually contains a number of components or additives which are oil soluble and can be considered parts of a single oil phase. The ease of emulsification and the emulsion stability of a soluble oil are principally functions of the energy of attraction between the water and oil phases. This energy should be high for emulsion stability, and varies inversely with the interfacial tension between the two phases. When the attraction between the phases becomes great enough the IFT approaches zero and the dispersed droplets become so small that the emulsion goes from milky to transparent as true solution is approached.

A stable oil in water emulsion of soluble oil can generally be considered to consist only of the two phases, aqueous and oil. When the soluble oil is mixed with water, some of the additive is extracted from the oil, and, in time, equilibrium may be reached with the additive distributed between the oil and water according to its partition coefficient. A minimum transfer of additive from the oil to the water is usually desirable for maximum emulsion stability. When a compound enters the water phase, it lowers the cohesive attraction of the water molecules for each other, as evidenced by a lowering of the surface tension, which tends toward emulsion inversion and poor stability. An oil in water emulsion requires the highest possible surface tension or molecular cohesion for the water to prevent its dispersion and to make it the continuous phase. The lowest possible surface tension or molecular cohesion is desirable for the oil to promote its scattering into the dispersed phase. The lowest possible interfacial tension or the greatest affinity between the oil and water phases is required to decrease the size of the oil droplets and prevent their coalescence.

A stable water in oil emulsion, like one of oil in water, requires a low interfacial tension between the two phases. However, since oil is now the continuous phase it should have the high surface tension, and the tension of the aqueous phase, which is dispersed, should be low.

The viscosity of a metal working fluid is often important and is determined by the requirements of a specific application. High viscosity oils are generally better hydrodynamic lubricants than low viscosity oils, but the latter are better carriers for surface active additives because of their fluidity; additives can reach a surface more readily from low viscosity oils which are hence most effective for boundary lubrication. Low viscosity oils are better coolants than high viscosity oils principally because of their faster heat transfer. Emulsions are generally better coolants than high viscosity oils for the same reason, and to a greater degree, because they contain water, which conducts heat faster and has a higher specific heat than oil. Oil in water emulsions are better for cooling but poorer for lubrication than water in oil emulsions. The latter can be effective lubricants because the exterior or continuous phase is oil, however, they are subject to breakdown and loss of effectiveness under shear. The viscosity of an emulsion is often important, and usually approximates the viscosity of the continuous phase, if this phase is predominant in quantity. However, if the continuous phase is less than the dispersed phase, the emulsion may become quite viscous, even if each of the phases is very fluid. This is apparently the result of restricted movement of the fluids due to the comparatively thin enveloping, continuous phase having a relatively high surface tension.

The determination of energies of adhesion at liquid-liquid and liquid-solid interfaces is believed to be very important in this field, and a step in the direction of more scientific development of the best fluids for specific field applications.

## MODERN METHODS OF METALWORKING

According to conclusions of an Air Research and Development Command report (6), its ARDC-TR-56-2, prepared by Taylor and Kniesche, usage of high-temperature metals in airframes is expected to reach 70% by 1965. In contrast, such usage in 1956 was only 10-15% of total metal poundage in airframes.

The over-all trend to meet fabrication problems, has been (a) development of improved tool materials, (b) metallurgical advances to combine requirements in end-use properties of metals with reasonable formability, and (c) new methods for metal-removal and shaping.

In addition to modifications in known machining methods, a variety of new forming techniques is becoming increasingly used.

Since considerations of lubricating practice and the application of forming lubricants and fluids are of principal concern here, these new methods may be classified in two general categories, as follows:

TABLE 3

MODERN METALWORKING METHODS

*GROUP A*—Involving requirements for surface-active fluids or other metalworking lubrication.

1. Cold press extrusion (chipless machining).
2. Rotary extrusion (power spinning).
3. Radial draw forming, compression-form, creep-forming, and others.
4. Roll forming.
5. Hot-forging and precision hot-extrusion.
6. New machining methods, trepanning, improved carbide and ceramic tooling.

*GROUP B*—Involving requirements for fluids used principally as pressure—or energy transfer-media, electrolytes, etc.

1. Explosive (high-energy-transfer) forming.
2. Spark-discharge machining.
3. Chemical milling.
4. Electrolytic machining.
5. Ultrasonic machining.

The first of the above processes, namely, cold press-extrusion, had its commercial origins in Germany during World War II, where scarcity of alloying additives for steel forced the development of cold-working methods to improve physical properties of low-alloy and carbon steels (7-8).

Extrusion, per se, is generally well enough known to require no detailed explanation here. Forward and backward extrusion, and various modifications of these, as well as cold-heading processes to plastically form new metal shapes, are largely dependent upon three factors, (a) mechanical aspects of press design and power supply, (b) metallurgical conditions of dies, tools, and work materials, and (c) chemical aspects of required lubrication.

Of these, the last has probably been most important from the very beginning. Basically, lubrication here means application of a tightly bound, absorptive, crystalline coating over which a soap or fatty ester type lubricant film is used to facilitate forming.

For carbon steel, the base coat is usually a zinc phosphate application. Supplementary lubricating films may be rapeseed oil, wool, fat, tallows, or emulsion lubricants containing small concentrations (2%) of sulfonated tallows, soaps, lard, chlorinated waxes, and fatty acids in dilute stearate solutions (9).

For stainless steels and many of the high nickel alloys, an oxalate base coating is applied (10). For zirconium and its alloys, a fluoride type coating has been developed (11) and for tantalum and aluminum, a strong alkali coating is in the development stage.

Cold working and extrusion of nickel- and cobalt-base alloys below their recrystallization temperatures, appreciably enhances their mechanical properties. The term cold-extrusion does not necessarily relate to ambient temperatures, but infers simply a mechanical working below the temperature of recrystallization for the particular metal, as mentioned previously. Parts so produced are of necessity work-hardened and hence, stronger.

Whereas, cold extrusion and impact extrusion of ordinary metals such as copper, aluminum, tin, zinc, and their alloys, has been known for some time, and accomplished with conventional soap, fat, and wax-type lubricants, newer developments in this field now encompass working on titanium (type A70), molybdenum, columbium, tantalum, and a number of ferrous alloys (12).

Special machines for cold-forming by one chipless machining process (13) utilize a rapidly pulsating die to impress a mandrel profile by a metal squeezing action on the interior surface of cylindrical stock. Chipless machining and forming of many industrial parts are being increasingly developed and improved every day. For forming of copper-soldering-iron, for example, chipless machining methods using wax-type emulsions as lubricant, have been found advantageous.

Rotary extrusion, power spinning, and roll-flowing all have reference to a metal-forming process which is basically a rotary extrusion.

Power spinning, in one commercial process (14) is a process wherein a metal preform takes the shape of rotating, hardened mandrel through extrusion induced by the action of form rollers. Dependent on the shapes produced, related techniques are designated as tube spinning, contour spinning, and shear spinning, the latter producing conical shapes from a flat disc preform.

The amount of cold work put into a metal by power-spinning is only exceeded by that from wire drawing, and is greater than the work done in cold-extrusion by press methods. Consequently, under proper conditions of forming, and with adequate lubrication, the opportunity for improving mechanical properties of the work-metal is significant.

The size and power input of roll-flowing, spinning, and other rotary extrusion machines is increasing rapidly. Whereas smaller machines, up to 50,000 lbs. thrust in the toolslides and tail stock, are fully capable of forming stainless steel (type 430) nose cones, some newer, larger machines powered by 3,000 psi hydraulic systems will have available over 200,000 lbs thrust in opposed toolslides and tail stock (15).

Lubricants, usually a viscous oil type to withstand temperatures and high pressure, are applied generously. For light gauge metals, water-based fluids may also be used. White lead and linseed oil blends, or lithopone mixtures have been used, as well as high titre soap coatings. Spinning lubricants are removed before annealing, which, in the case of the austenitic stainless steels, must follow quickly after forming to prevent "season cracking" (16).

A number of new methods for forming metal components, particularly sheets and thin sections, have been developed to minimize "spring back" and other aberrations from desired finished form, and to utilize the metallurgical benefit of cold-working, with resultant increases in strength.

Typical of such new methods is a radical draw process (17) different from more conventional forming in that the work-metal is progressively stretch-formed along a die rotated in a given plane. Concurrently, a side compression unit wipes a shoe or roll across the outer surface of the work piece, and along the contour of the die, controlling the thickness or cross-section of the formed piece by compressive force.

Compression forming (18), a rubber pad method, uses pressure on a rubber form pad inside the part to fill the die interior, and compressive force endwise to the flanges to set the metal. The method accomplished the same results as stretch forming, except by compression.

Stretch-wrap forming and creep-forming (19) at elevated temperatures are other methods devised to control elongation, springback, buckling, and distortion of thin-section aircraft structural components.

Roll forming, or contour rolling (20), combines forging, extrusion and rolling in a process to form high strength alloys accurately and without waste. A typical job consists of contour-rolling four identical quarter sections of a jet engine turbine case. These are then welded together and given a final machining to remove weld beads. Flat dies and a forming roll are used which applies roll pressure on heated work blanks loaded on the bed of a rolling press. Because it is hot working, powdered graphite die lubricants dispersed in various aqueous and oil vehicles are commonly used.

Forging presses in recent years have grown increasingly in size and capacity. Even the giants of 35,000 to 50,000 ton capacity are now reported to be exceeded in size by a new Russian unit claimed at 77,000 tons, for working light metal alloys. When complete, this press will be the largest in the world (21). Where presses of smaller size only are available, forging engineers use sectional forging techniques. Forging metals today run the gamut, from light-metal magnesium and aluminum alloys, titanium, and steels to molybdenum and a variety of the new super alloys. Forging work temperatures range from 500-600F for magnesium and aluminum, to 1500F for titanium, and 2000-2200F for steels and super alloys. Forging die temperatures for normal forging are about 400-600F.

Forging lubricants may be either aqueous—or oil-based dispersions of solid lubricants such as graphite in one of its several forms, molybdenum disulfide, tetrafluoroethylene resins, and certain ceramic materials (22).

Predipping of billets in aqueous graphite suspensions, with subsequent die application of oil-type lubricants is advantageous. Pre-etching of aluminum with sodium hydroxide preceding a graphite solution dip is additionally helpful (23).

Forging of molybdenum follows the normal practice for steel forging except that high impact speeds are used for maintenance of metal flow, to avoid cold-work stressing and cracking. Also, oxidation of molybdenum is a problem, due to rapid formation of molybdenum-trioxide, a whitish powder which builds up rapidly on tools, making them slippery, and causing irritation to operators through inhalation and ingestion of the fine powder. A high-speed suction-exhaust fan placed at the forge is one method for correction. Protective coatings on the molybdenum billet have also been used (24).

In tooling for modern machining, probably the most important recent developments are use of harder carbides, typically titanium-molybdenum carbide with a nickel binder (25) and ceramic cutting tools. There has been some concern regarding tool breakage in "roughing" and interrupted cutting. The ceramic tools have been considered suitable for finish machining of hard and abrasive materials (26). Mechanical clamping of ceramic tools is essential for strength, in which case, unequal stressing must be avoided, as well as vibration. Shaw and Smith (27) have found varying degrees of compatibility in the attraction of cemented carbides and ceramics for various work metals during machining. In applying ceramic oxide tools for heavy rough-machining of type 4330 steel tubes for 120 mm tank guns at Watervliet arsenal, Rodd and Hutson (28) placed a thin shim of aluminum foil, 0.0015 inches thick, between the ceramic oxide tool and the carbide seat in the tool holder. This expedient compensated for surface irregularities at the interface, giving the effect of greater contact area, with better shock resistance, when machining with negative tool geometry at 280 sfpm.

Generally, water-based coolants, i.e., soluble oil emulsions, solutions, and colloidal suspended coolants are used with carbide or ceramic tools in production machining. However, some jobs are machined dry, dependent upon certain conditions of operation. The coolant where used, should be applied in full active flow both in the rake and clearance crevice for best results, to secure uniform flooding of the work area, to prevent the tool being alternately overheated and suddenly cooled. If uneven cooling occurs, it may result in an alternate quench action which could cause spalling of the tool surface (29).

Another mode of cooling, the whole purpose of which is to prevent welding of chips on the tool, is by spray or mist application of an aqueous solution. This has the advantage of uniformity and simplicity in application, hence resulting in more efficient cooling.

Ceramic tools have an advantage over carbides within the permissible limits of top cutting speed under identical conditions. The life of a ceramic tool at 1500 sfpm is about equal to that of a carbide at 500 sfpm. Recent evaluation tests of ceramic tools have, with suitably powered machines, indicated cutting benefits at speeds up to 18,000 sfpm (30). These tests were made in machining AISI 1045 carbon steel with ceramics, producing a 15 micro inch surface finish with satisfactory tool life.

The Russian Machine Tool Research Institute has carried out machining tests with ceramic tools, reportedly milling aluminum and bronze alloys at speeds of 20,000 to 28,000 sfpm without undue tool wear (31). All these high-speed trials were made under dry cutting conditions.

Obviously, speeds on this order are not tenable for machining the new high-strength metals. Although aluminum is regularly machined in production spar and skin mills at up to 15,000 sfpm, heat-treatable alloys of steel, titanium, etc., are normally cut at between 100 and 400 sfpm depending upon prior heat

treat and metallurgical condition of the metal. In some cases, steels with Bhn of 400 are machined in routine production. However, if maximum cutting speeds are exceeded, tool troubles and failure result.

In modern methods of gun drilling, deep hole boring, and trepanning, carbide tooling plus specially developed light, chemically-active cutting fluids have played an important role in increasing cutting speeds, improving the finish and dimensional accuracy of work, yet prolonging tool life measurably (32).

Filtration of cutting oil used for deep drilling is an important adjunct to its efficiency. Some operators of trepanning equipment, in the interest of securing better cooling for the deep hole work and carbide tools, use water based fluid, essentially soluble oil emulsions (33) at conventional dilutions, i.e., ca 1:15 oil/water ratios. Here, also, the chip-laden coolant coming from the trepanning bar is screened before returning to the sump.

For some metals, like beryllium, no cutting fluid should be used in machining. Due to its toxicity and that of its various compounds, certain precautions in handling beryllium are necessary. Avoiding the use of cutting fluids permits easier chip collection and facilitates evacuation by vacuum system. It also prevents contamination and devaluation of chips as scrap.

In machining beryllium, whether with tungsten carbide or ceramic tools, the process of chip formation, according to Walker (34) is essentially one of brittle fracture, irrespective of cutting speed, feed, or tool geometry, although some small amount of plastic flow, as with more ordinary metals, may be observed.

Where machining the more refractory modern metals, Schmidt (35) has proposed "a systematic approach using novel experimental techniques such as confined hot machining, faster spark machining, and newly developed tool materials—to make possible further advances".

The following section of this paper discusses briefly some of these new and novel metal-forming methods which do not utilize a cutting fluid, lubricant, or coolant in the sense usually associated with conventional metal-working practices. However, both water-based and oil-type fluids are employed in one or another of these methods, principally for purposes of energy transfer, hydraulic action, dielectric properties, electrolyte, etc.

Explosive forming, which is more accurately described as "high-energy-rate forming", utilizes the phenomenon wherein metals deform more readily under conditions of ultra fast stress loading at high unit pressures (36). Conventional forming methods operate at displacement velocities of something less than 5 ft per sec. High-energy-rate forming, using an explosive for source of energy, operates usually at displacement speeds well over 400 ft per sec. The method requires only one female die into which forming is accomplished by energy transfer through air, gas, water, oil, rubber or some other flexible medium. Die materials range from plaster and plastics to tool steels.

The results of new studies in this field may indicate better energy transfer media than present ones. Talc, foamed plastics, and plastic beads are some solid media already suggested to replace the ordinary water and oil type fluids.

Operating with unit pressures of ca 4 million psi during time cycles of only several milliseconds, the process has successfully shaped refractory metals that could not be formed in any other way. Light metals are hardened by the process, and spring-back in large-area, thin-section pieces is practically eliminated. This is considered due to a reverberatory or hammering effect at the end of the forming action induced by initial shock wave from the charge.

Another interesting method for removing and shaping difficult metals is the technique referred to as Electrical Discharge Machining. There are two variations of this process. These two methods may be designated (a) Spark-over Initiated and (b) Contact Initiated. They differ with respect to the nature of coolant and the mode of metal removal (37). In general, the process consists of a series of electrical discharges occurring at the rate of 20,000 to 300,000 cycles per second, between the tool and the workpiece, where the tool acts as the cathodic electrode and the work-piece is the anode in the couple (38).

In the Sparkover Initiated process, the tool and work piece are separated by a dielectric fluid, usually a light viscosity petroleum oil, refined kerosene, or in some cases a silicone fluid. Upon application of sufficient electrical energy, the dielectric is ruptured and a heavy discharge current flows through the ionized path. The electrical force fields then effect the material removal. Energy flow is spaced in intervals to allow a make and break of current flow through the dielectric fluids. This dielectric fluid should have a reasonable flash point for safety, low viscosity for fluidity, particle settling, and cooling, and a high availability of positive ions to allow passage of high peak discharge currents when ruptured. Semi-solid dielectrics derived from residues of petroleum cracking, and some typical microcrystalline waxes have proven useful.

In operational machining of various non-radioactive metals, including normal uranium, one user (39) of the process evaluated commercial transformer oils, silicone oils, carbon tetrachloride, and distilled water as fluids. Transformer oil is efficient in this service, but was found to deteriorate to some extent, forming a carbon sludge, and also releasing hydrogen. Silicone oils perform well in light viscosities and are more stable than oils, but are quite hard to remove, and are also costly. Carbon tetrachloride, tried because of its high vapor pressure and easy disposal, broke down rapidly, releasing chlorine, phosgene, and a carbon sludge. It is not considered safe to use. Distilled water was found particularly useful for cutting uranium, because chips were oxidized, eliminating a fire hazard and simplifying disposal. However, upon use, the water becomes contaminated with soluble compounds which reduce its dielectric properties, necessary in the Spark-over Initiated Discharge Process.

This drawback is not found in the second of the two methods known as Contact Initiated Discharge wherein, after initial contact of tool and work, an arc is allowed to form, and the duration of discharge is controlled by the reciprocating motion of the tool or electrode. Here, an aqueous coolant is normally used. During the time of arcing, the spot temperature rises,

which upon interruption in the presence of an active coolant like water, causes localized quenching, thermal shock to the work area, successive fracture and then breaking away of work particles.

In Discharge Machining generally, tool wear (i.e., of the electrode) occurs in a ratio to work metal removal of from 1 to 15 to 3 to 1, dependent upon energy rate hardness of the work metal being cut, flushing techniques, etc. Metal removal rates are generally low, ca 1 to 5 cu in./hr, dependent upon the nature of the work metal. The method is useful for small die cavities, tool sharpening, piercing, trepanning, and similar operations on tools and dies.

Another method utilizing electrical current between tool and work is variously known as Electrolytic Machining or Electro-Chemical Machining. This process differs from the electrical discharge method in that the work material is removed by electro-chemical attack rather than by electrical sparking or arcing (40). In this respect it is similar to chemical milling which will be described later.

The electrolytic process utilizes an electrolyte, this normally being a neutral aqueous salt solution, between the electrode (tool) and work. The latter acts as the positive electrode or anode, which in the cell action of the process is hence removed under controlled conditions. The metal so removed goes into solution in the electrolyte, forming metallic salts of the work metal, just as in chemical milling. Dependent upon the work metal, the solution takes the color of the dissolved salts, i.e., nickel-green, chromium-yellow, etc. Where the material is basically non-ferrous, a somewhat different electrolyte may be required to secure the proper electrochemical action (41). The advantages of this method over some others used for machining exotic metals are principally:

1. High rates of metal removal
2. Contour accuracy under these conditions
3. Minimum electrode consumption
4. Safe operation

Whereas Electrical Discharge Methods are limited roughly to 200 amperes input current, Electrolytic Machining power, and consequently metal removal rates, are less limited. For example, the Table 4 shows the latter's commercial possibilities.

TABLE 4

ELECTROLYTIC MACHINING—METAL REMOVAL RATES

| RATING (Amps) | METAL REMOVAL (in.$^3$/hr.) | MIN. ELECTRODE AREA (in.$^2$) |
|---|---|---|
| 500 | 3 cu. | 3 |
| 1,000 | 6 cu. | 6 |
| 5,000 | 30 cu. | 100 |
| 10,000 | 60 cu. | 200 |
| 50,000 | 300 cu. | 1,000 |

Another new method for metal removal from large-area surfaces, as encountered in the aircraft industry, and which is ideally adapted to obtain accurate complex contours, is known as Chemical Milling. Basically, it is an etching process. By masking certain areas of the work and immersing it in an acid or alkali etching bath, the etchant solution removes the unmasked portion of the metal surface to produce the desired shape or contour. From this it may be seen that it is strictly a chemical process, and hence different from electrolytic machining. For large work pieces or sheet metal areas, the latter is relatively limited by the electrical power requirements. Chemical milling is limited in this respect only by the size of the available tank (42). Etching solutions depend upon the metal being worked. Both modified caustic solutions and hydrochloric acid have been used on aluminum. The acid etch permits a very fine etching, although in general, caustic solutions are used for aluminum, and acid-type etchants on magnesium, titanium, and steels. Acid etchants are carried in mild steel tanks with plastic liners. Other type solutions are usually carried in unlined mild steel tanks. The etching action produces a black deposit on the metal surface, which is then removed by rinsing and immersion in a deoxidizing solution (chromic deoxidant) and subsequent rinsing and demasking. Chemical milling is best applied for metal removal from large surface areas to shallow depths, less than ca 0.5 inches.

Ultrasonic Cutting is another new machining process. In this method, the work is submerged in an abrasive dispersion, carried in an aqueous vehicle. The tool is actuated by a magneto-striction oscillator, from which vibration of a low amplitude is derived at a rate of 15,000-30,000 cycles per second. The tool motion drives the abrasive particles against the work surface, causing the desired removal of material. This method, different from others discussed for machining of extremely hard materials, does not require electrical energy transmitted through the work piece, and hence may be used to machine semi-conductors and non-conductors. It lends itself particularly to cutting of small precise electronic components, such as coated germanium or silicon discs for use in transistors, or ferrite wafers for computer memory devices (43).

## SUMMARY

It may be seen that many new developments in methods for working metals have accompanied the advent of these materials in this atomic age. It should be clear that some of these methods are as specialized as the metals for which they are intended. Hence, widespread general use for all of them is certainly not indicated at present.

However, in the current activity of tooling developments in the metalworking industry, many new ideas are having their effect in improvement of even the most conventional tools, machines, and methods.

A brief review of related functions of fluids in all metalworking processes discussed in this paper show that these may be summarized somewhat as follows:

**Fluid Functions**

1. Cooling
2. Lubrication
3. Other surface-active mechanisms, as:
   a. Adsorption
   b. Absorption
   c. Oxidation
   d. Chemical reaction
   e. Diffusion and others
4. Energy Transfer
5. Hydraulic Action
6. Dielectric
7. Electrolyte
8. Carrier (Fluid Vehicle)

Apart from special chemical effects, such as with the use of electrolytes, it is seen that a majority of requirements for fluids used in both conventional and newer processes have much in common. This "common-denominator" aspect can be helpful both in development and application of new fluids and lubricants in the metalworking field.

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# ASLE Technical Digest

**"Direct Reading Analysis Reduces Truck Operations and Maintenance Cost," by Charles Jackson, Pacific Intermountain Express**

The relation of used oil analysis to maintenance cost control is generally accepted. The evaluation of such analysis in the study of internal combustion engine wear, however, must be approached with respect to the possible contaminants which could reduce the lubricating value of the oil, and the metals and alloys which compose the engine. When abnormal wear is observed to have occurred in a certain part of the engine the associated element or alloy present in the lubricating oil will have been markedly increased. For example, increase in iron, copper and lead in the latter will indicate rapid wear of the copper-lead bearing metal on the iron crankshaft. Silicon in turn would indicate entry of dust via the air intake system. Cooling water leakage is revealed by boron in the oil analysis. Table 1 is a trouble chart showing indicated trouble versus metal contaminant.

TABLE 1

Metals and the inferences that can be drawn if they are present in greater than routine levels.

| *Metal Contaminant* | *Trouble Indicated* |
|---|---|
| Silicon | Faulty air cleaner or leak in air intake, or<br>Accelerated general engine wear |
| Copper, Lead, Iron | Copper-lead bearings wearing on iron crankshaft |
| Iron | Cylinder walls wearing |
| Chromium | Piston ring wear |
| Aluminum | Piston wearing |

Spectrographic analysis in company with certain chemical tests such as neutralization number are used to good advantage in laboratory determination of oil drain periods. The author cites preventive maintenance procedure whereby a sample of oil is taken from an engine every 7500 miles, being drawn from the crankcase while hot by a special suction gun via the dip stick tube so that samples always are taken from the same level. By use of a direct reading type of apparatus which is provided with 16 indicator dials calibrated for the elements involved and the established concentration ranges, approach to the critical point for each element is noted based on normal conditions and engine mileage. A feature of this apparatus is the fact that one minute after loading the sample, results are obtained simultaneously for each element in parts per million on individual indicator dials. For example, at 15,000 miles the normal silicon is 20 ppm; iron is 200 ppm; lead is 200 ppm; copper is 40 ppm; chromium is 8 ppm; aluminum is 20 ppm, etc. In addition to being of value as an indicator of the condition of used oil this same device can be used to check the normal element content in new oil.

The principle is based on subjecting the sample to a high voltage spark which causes the various elements in the oil to emit light of characteristic wave length. The oil sample is analyzed directly as received by use of a rotating disc electrode technique which eliminates need for intermediate sample preparation. A graphite disc rotates in a small boat holding the oil sample so that a continuous film of oil is sparked during exposure.

Direct reading analysis has been proved to be so rapid, reliable and accurately reproducible with respect to engine maintenance that presently it is hoped to extend the procedure to transmissions and differentials. Reducing the cost of maintenance is of course the major objective; if by use of this method of oil analysis, emergency breakdowns also can be forestalled, the initial cost of the laboratory set-up becomes well worth while.

*(Digested by A. F. Brewer)*

# Lubrication Abstracts

Edited by W. E. Campbell

Selected literature compiled by members of the Technical Committees and Industry Councils of the Society.

**by S. Whitley (United Kingdom Atomic Energy Authority, Chester, England) and C. Betts. *British Journal of Applied Physics*, "Study of Gas-Lubricated, Hydrodynamic, Full Journal Bearings," v. 10, no. 10, 1959, 455-63.**

The two most important characteristics of gas-lubricated, full journal bearings are load-carrying capacity and half-speed whirl. In this paper these two characteristics have been investigated. The gases used as lubricants were mainly hydrogen, nitrogen and neon, giving a large viscosity variation; argon and carbon dioxide were also used to investigate the effect of the ratio of specific heats. The bearings used were plain cylinders with a longitudinal groove cut into the upper surface of each bearing, extending over half the bearing length. It had been shown previously that this groove improved the half-speed whirl characteristics, and tests on bearings without the groove, included in the paper, demonstrate that the groove does not affect the load capacity.

The parameters investigated are bearing length, diameter, clearance, rotational velocity, ambient pressure, and the gas viscosity and ratio of specific heats. It is shown that, in general, the existing theories of load performance for compressible lubricants, operating in isothermal conditions, give a satisfactory correlation with the experimental results. The half-speed whirl results are not related to a complete analytical theory, but useful stability criteria are established. *(Author Abstract per T. Osters)*

**T. W. Morrison (SKF Industries Inc., Philadelphia, Pennsylvania) and T. Tallian, "Tests for Smooth-Running Rolling Contact Bearings," *Elect Mfg.*, v. 64, no. 11, 1959, pp. 100-6, 182.**

An antifriction bearing is said to be smooth running, if the machine or apparatus equipped with this bearing runs without objectionable audible noise and without harmful or excessive vibration. The unusual procedure is to check the smooth running quality of a bearing by ear or by measuring the shaft runout. This method is subject to human discretion. A more advanced means of testing the running quality of a bearing is by means of noise or vibration measurements. Instruments for this purpose are described. Essentially these instruments consist of a spring loaded stylus which contacts the stationary outer race of the bearing. The bearing is mounted on a mandrel and an axial load applied sufficient to take up the internal bearing looseness, and to eliminate cage rattle. The movement picked up by the stylus generates an alternating voltage proportional to the vibrational velocities imparted to it. The most critical consideration in the measurement of bearing vibrations is that of frequency. It has been found that a frequency of 250 CPS and below does not influence the noise of machines in which the bearing operates, however it does influence chatter produced by machine tools. The medium frequency range, around 1000 CPS is important in testing quiet running. The high frequency range above 3000 CPS is considered the least reliable in evaluating basic bearing characteristics as it is affected by many outside factors not primary to the bearing itself. If a uniform technique of bearing vibration could be resolved many of the differences in results obtained by bearing manufacturers and users could be eliminated. The causes of bearing vibration are clearly outlined based on a number of years of research, and considerable time and effort is and has been expended into correlating vibration measurements with the noise level and with waviness of the balls or rollers and races. *(Abstractor: Weldon C. Cook)*

**E. Jann (Shell, Switzerland), "Practical Experience in Lubricating Diesel Engines," Schweizer Archiv für ang. Wiss. and Technik, v. 24, n. 10, 1958, 219-225 (in German).**

The fundamental investigations made by N. Kendall and L. R. Richards (Schweizer Archiv für ang. Wiss. and Techn., v. 22, n. 8, 1956) are first reviewed. These showed that acidic condensates developed during fuel combustion greatly influence the amount of wear as well as lacquer formation, and that these condensates can be neutralized by alkaline additives. Based on these results, the development of heavy-duty oils for large two-cycle diesel engines and their first use for a power plant in Switzerland are reported. During these investigations, scavenging pressure rise was used as an indication of deposits in ports. A thorough discussion, with examples of application, is given of the spot-test method for determining the condition of used oils. *(Abstractor: George C. Lawrason)*

# Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

**Method of Preparing Oil Soluble Sulfonates,** Patent #2,924,618 (R. L. Anderson and H. McDonald, assignors to Continental Oil Co.) A process for the production of light colored oil soluble alkyl benzene sulfonates substantially free of oil insoluble alkyl benzene sulfonates from a mixture of alkyl benzenes which comprises: sulfonating said mixture of alkyl benzenes with a sulfonating agent selected from the group consisting of sulfuric acid and oleum under sulfonating conditions, diluting the resulting reaction mixture with 3 to 7 parts of a white oil, having a viscosity varying from 70 to 170 SSU at 100 F., per part of said mixture of alkyl benzenes, allowing the diluted reaction mixture to separate into two liquid phases, an upper phase comprising said white oil having dissolved therein oil soluble alkyl benzene sulfonic acids and unsulfonated alkyl benzenes and a lower phase comprising spent sulfuric acid, oil insoluble alkyl benzene sulfonic acids and color precursors, removing the lower phase from the upper phase within 24 hours, blowing the upper phase with an inert gas to remove $SO_2$ and $SO_3$ therefrom, treating the upper phase with an activated earth type filter aid, filtering the upper phase to remove said filter aid, diluting the upper phase with about one part of methanol per part of alkyl benzenes, allowing the methanol diluted upper phase to separate into two liquid phases, a lower phase comprising the methanol having dissolved therein the oil soluble alkyl benzene sulfonic acids, and an upper phase comprising said white oil having dissolved therein the unsulfonated alkyl benzenes, separating the phases, removing the methanol from the lower phase to obtain therefrom the alkyl benzene sulfonic acids, and then neutralizing the alkyl benzene sulfonic acids.

**Mineral Oil Compositions,** Patent #2,928,789 (T. P. Sands, assignor to Monsanto Chemical Co.) A lubricating composition comprising a mineral oil and with respect to the mineral oil about 0.1-10% by weight of an oil soluble metallo hydrocarbon sulfonate detergent, about 0.05-3% by weight of an oil soluble phosphorized- and sulfurized-dicyclic terpene, and about 0.05-2% by weight of an oil soluble sulfurized-monocyclic terpene.

**Preparation of Oil-Dispersible Highly Basic Sulfonates,** Patent #2,924,617 (O. L. Wright, assignor to Continental Oil Co.) A method of preparing an oil-dispersible highly basic alkaryl sulfonate which comprises reacting an alkaryl sulfonic acid with a quantity of ammonium hydroxide in excess of that required for neutralization of said sulfonic acid, whereby a mixture of ammonium alkaryl sulfonate and an alkaryl sulfonamide is produced, heating said reaction mixture to a temperature within the range of 180-220 C. for a period of time sufficient to decompose all the ammonium sulfonate present, diluting said product with an organic solvent which forms an azeotropic mixture with water, adding the resulting solution to an alkaline earth metal compound wherein the anion of said compound is selected from the group consisting of an oxide and a hydroxide dissolved in a polar solvent selected from the group consisting of ammonium hydroxide, saturated aliphatic alcohols containing up to 4 carbon atoms and ethanolamine at a temperature of about 100 C., and then removing said solvent and any water present by evaporation to form the highly basic alkaryl sulfonate.

**Lubricant Composition,** Patent #2,916,447 (D. J. Groetch, assignor to Standard Oil Co.) A spark-ignition internal combustion engine lubricating oil composition comprising a major proportion of a petroleum lubricating oil and in combination therewith from about 0.5% to about 15% of an oil-soluble polymeric alphamethacrylic acid ester of a monohydric saturated aliphatic alcohol containing from about 4 to about 18 carbon atoms, from about 0.5% to about 10% of a polyvalent metal, phosphorus, and sulfur-containing neutralized reaction product of a phosphorus sulfide and a normally non-gaseous hydrocarbon, lubricating oil detergent additive, and from about 0.5% to about 10% of a condensation product of a chlorinated long-chain alkyl hydrocarbon having from about 10 to about 50 carbon atoms and an aromatic compound selected from the class consisting of a mononuclear aromatic hydrocarbon, a mononuclear hydroxyaromatic compound, a dinuclear aromatic hydrocarbon and a dinuclear hydroxyaromatic compound, said condensation product being used in an amount sufficient to reduce the octane requirement increase induced by said ester and said detergent additive.

**Petroleum Hydrocarbon Oil Stabilized Against Oxidative Deterioration,** Patent #2,928,790 (J. D. Bartleson, assignor to Ethyl Corp.) Petroleum hydrocarbon oil normally tending to deteriorate in the presence of air at elevated temperatures below the cracking temperature of the oil containing from about 0.05 to about 2% by weight each of a $P_2S_5$-dicyclic terpene reaction product and a 3,5-dialkyl-4-hydroxybenzyl amine.

(*Continued on page* 51)

## PATENT ABSTRACTS

(*Continued from page* 50)

**Corrosion Resistant Sulfurized-Phosphorized Extreme Pressure Lubricant,** Patent #2,929,-778 (A. A. Manteuffel, G. W. Ayers and W. D. Gilson, assignors to The Pure Oil Co.) A lubricant composition consisting essentially of mineral lubricating oil, from 5 to 20% by weight of lard oil which has been reacted with 5 to 10% by weight of sulfur and then with 0.4 to 5% by weight of phosphorus sesquisulfide until the product is substantially noncorrosive as measured by the copper strip test, from 0.1 to 5% of sulfur, about 0.5 to 2% by weight of dibenzyl disulfide, and a material from the group consisting of alkyl, aryl and arylalkyl phosphites and phosphorotrithioites in an amount of about 0.5 to 4% by weight.

**Compositions for Engine Operation,** Patent #2,913,413 (J. E. Brown, assignor to Ethyl Corp.) A liquid hydrocarbon crankcase lubricating oil containing from about 0.05 to about 10.0 weight per cent manganese as manganese pentacorbonyl.

**CORRECTION**—Figure A1 (below), which appeared in error on page 586 in the December, 1960 issue of *Lubrication Engineering*, should have appeared on page 582 along with Mr. Douglas Godfrey's Discussion of "The Transition From Boundary to Mixed Friction," by Mr. Ronald L. Lenning, Senior Research Eng., The Cincinnati Milling Machine Co., Cincinnati, Ohio.

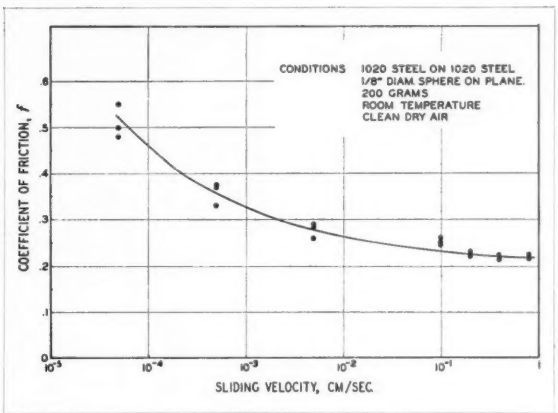


**Fig. A1. Friction of Mineral Oil (U.S.P.) in low speed friction apparatus.**

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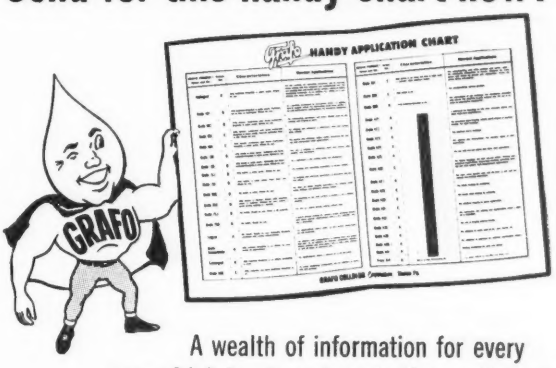
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## SECTION NEWS

(*Continued from page 7*)

***Pittsburgh*—A record breaking crowd listened to an interesting discussion on the subject, "Plant Maintenance Problems and What To Do About Them," at the November meeting. Gabe Almasi, Crucible Steel Corp., is shown directing a question on Maintenance to to Kenneth Hunt, also of Crucible Steel Corp.**

**Thirty-eight people were in attendance at the November 22 meeting of the Hudson-Mohawk Section when Mr. Clyde A. Sluhan, President, Master Chemical Corp., Toledo, Ohio, spoke on the subject, "The Role of Coolants in Machining and Grinding." Mr. Sluhan emphasized the reduction of production costs, the importance of cleanliness and good housekeeping to avoid bacteria growth and limitations of the coolant. Pictured left to right: S. J. Murray, Secty.-Treas.; C. A. Sluhan, Speaker; R. E. Lee, Jr., Chairman; R. V. Klint, Vice-Chairman.**


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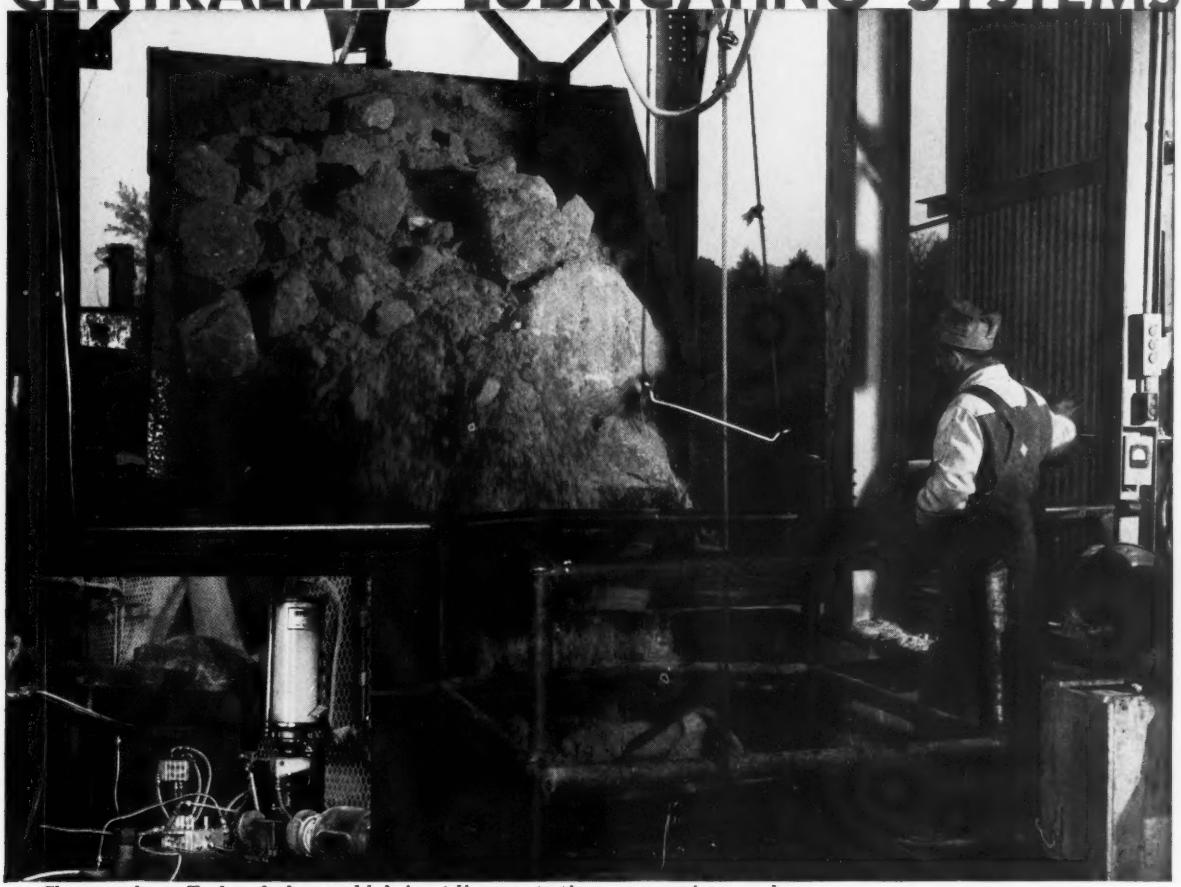

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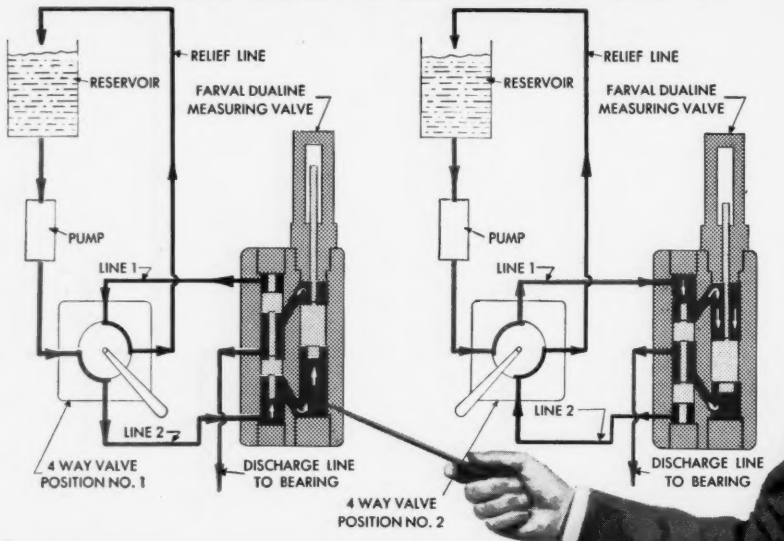


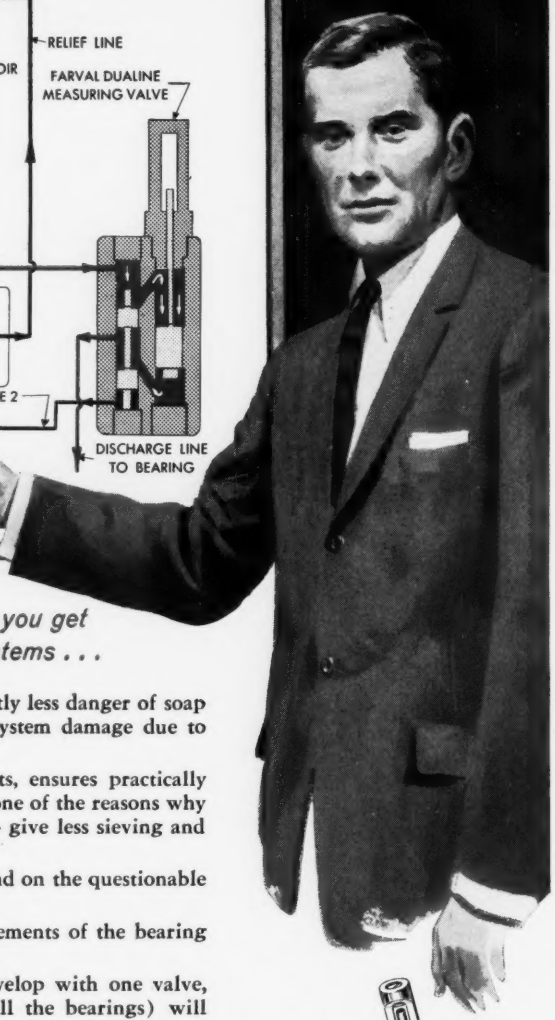

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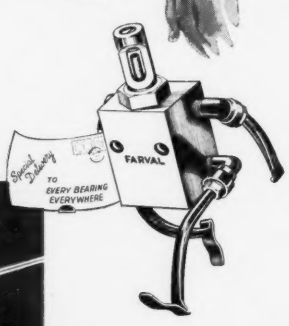


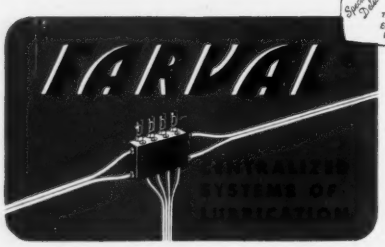


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